This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

**Usage guidelines**

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

**About Google Book Search**

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

NATURAL SCIENCE
TN
226
.A3
1903
no8

BUHR B
[redacted] [redacted]
a3[redacted]15 00002202 3b

NATURAL SCIENCE
TN
226
A3
903
.8

869

GEOLOGICAL SURVEY OF CANADA
ROBERT BELL, M.D., D.Sc. (CANTAB.), LL.D., F.R.S., I.S.O.

# MINERAL RESOURCES OF CANADA

## BULLETIN

ON

# MICA.

BY

R. W. ELLS, LL.D., F.R.S.C.

OTTAWA
PRINTED BY S. E. DAWSON, PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1904.

No. 869

THE UNIVERSITY OF MICHIGAN LIBRARIES

Natural Science
Library
TN
226
.A3
1903
no.8

# MICA DEPOSITS OF CANADA

By R. W. Ells.

The occurrence of mica in large and important deposits, at several points in eastern Canada, was recognized by the officers of the Geological Survey, almost from the commencement of the study of the crystalline rocks, and several references to this mineral are found in the earliest reports of the department. The true economic value of the mica deposits was not however ascertained until a comparatively recent date.

Its intimate association with apatite at many places was disclosed during the working of the latter deposits many years ago, but down to within the last fifteen years the mica was regarded practically of but small importance, and the quantity necessarily extracted in the removal of the apatite was thrown out on the dump. Around many of the old apatite mines, even at the present day, large quantities of this mineral, now rendered useless from long exposure to the weather, can be seen.

Chiefly used for electrical purposes.

Generally speaking it may be said that mica came into marked prominence owing to the discovery of its fitness as an adjunct in the manufacture of dynamos and other electrical appliances, and as a consequence not only were many of the old mines, which were worked for apatite up to the decline of the market for that mineral some years ago, and in which mica was known to occur in considerable quantity, reopened, but its presence was soon ascertained in other portions of the crystalline rocks which had hitherto been unexplored. Many of the properties thus taken up as probably mica-bearing were soon abandoned, owing doubtless to the limited extent of the deposits in some cases, or to the inferior quality of the mica in others, but some of these have been developed into large and profitable mines which have been worked almost continuously for many years.

Practically, at the present time, all the mica mining in Canada is confined to the provinces of Ontario and Quebec, with the exception of an area found in the Rocky mountains near Tête Jaune Cache, B.

C. The mica at this place occurs in a pegmatite dyke largely composed of quartz and feldspar, which cuts garnetiferous mica schist and gneiss, the mineral occuring in large clear crystals near the hanging wall. A description of this locality is given by Mr. James McEvoy in the Annual Report for 1898, Vol. XI, pp. 80-81, and is as follows:—

Mica in British Columbia.

'On one of these veins the Bonanza mica claim is located, seven miles south of Tête Jaune Cache, 5300 feet above the level of the Frazer river. The vein is about fifteen feet wide, where an opening has been made, dipping S. 45° W., conformably with the country rock. Its continuation toward the north-west is covered with talus from the mountain, while on the south-west side of the opening the original top of the deposit is seen covered by the mica-schist. At the time of our visit, Messrs S. Winter and J. F. Smith, with a party of ten men, were engaged in taking out and cutting mica intended for shipment by pack-horses to the nearest railway point. The quartz, feldspar and mica are separated into large masses, the crystals of mica being frequently eighteen inches long and eleven inches wide, and are found in greatest abundance near the hanging wall. It is evident that the mass was cooled at a great depth and very slowly to permit of this great amount of segregation. While practically no work has been done with a view of proving the extent of the deposit, it may reasonably be expected, from what actually appears, that a large quantity of mica can be obtained here. The mica is a transparent muscovite with a light greenish cast and is otherwise of excellent quality. The probabilities of further important developments appear to be favourable.

'Another claim, owed by some Edmonton miners, is situated a few miles south-east of the Bonanza. Fifteen miles to the south-east on the mountains, near the head waters of the Canoe river, several claims have also been staked. On one of these some work has been done, exposing a deposit of marketable mica. It may be expected that further discoveries of valuable mica deposits will be made in these rocks, which are of the same character for a distance of twenty miles at least, and probably much furthur.

'A great hindrance to the development of this or any other mining industry in this part of the country, is the difficulty of travelling without proper trails. It requires seventeen to twenty days to reach Tête Jaune Cache from Kamloops, a distance of 215 miles in the present state of the trail. From Edmonton to the Cache, a distance of about 350 miles, requires ordinarily twenty-five days, but in a very favourable season the distance might be covered in twenty days. It will thus be seen that, apart from the question of shipping out the

products of the mine, the greater part of the short season available is wasted in travelling to and fro. A moderate sum of money, if properly expended on these routes, would put them in a fairly passable condition.'

## Ontario and Quebec.

The mica bearing formation in eastern Canada belongs to that division of the crystalline rocks known generally as the Grenville and Hastings series, which to a great extent are now regarded as geological equivalents. They form part of what is usually styled the Laurentian system. While mica in small scales is an essential constituent of the granites and gneisses which form the great bulk of these rocks, the merchantable micas are always associated with intrusive masses and dykes of more recent date, which cut the gneiss and crystalline limestone at many points.

Mica-bearing rocks.

The mica-bearing dykes are usually of two kinds, viz., pegmatite-granite and pyroxene. The former consists largely of feldspar, both white and red, with quartz; the latter is probably an alteration from a hornblende diorite. In the light-coloured pegmatite the mica is generally a white muscovite, while the pyroxenes carry phlogopite or sometimes biotite, the latter being a blackish variety, having a large percentage of iron in its composition. As a rule it may be stated that the lighter coloured the matrix the lighter the tint of the contained mica, and when the dyke is composed of hard and dark material, the mica is usually a hard and brittle variety of little commercial value.

Principal mica areas

While it might be supposed that with the great extent of crystalline rocks in Canada, the presence of merchantable mica would be common over very large areas, or throughout their entire distribution, such, however is not the case, In fact it may be said that the mica-bearing belt is practically confined to a particularly limited area where certain kinds of eruptive rocks are readily recognized. Among the principal places where mica is found in large quantities, the following may be mentioned: A considerable district north of the Ottawa river along the lower portion of the Lièvre and Gatineau rivers and in the area adjacent for some miles; an area about the lower Rideau lake lying to the south and west of the town of Perth—the occurrences being mostly in the township of North Burgess—and a considerable area lying to the west of the Rideau canal, extending north from the village of Sydenham to the vicinity of Sharbot lake. In addition to these, several smaller areas are known in which local

deposits of mica are found, but in none of them are the conditions so widely spread or the areas so large and generally important as in the three first mentioned.

Varieties.

Mica mining in Canada at the present day is practically confined to the phlogopite variety. A small amount of muscovite is occasionally produced, but the output may be regarded as insignificant compared with the large quantity of the former variety. Muscovite is usually known as a potash mica, and is a silicate of alumina with potash and a small percentage of iron with water; phlogopite is a silicate of alumina and magnesia and contains also potash and sometimes fluorine. Biotite is related to the latter but contains a marked percentage of iron in its composition to which the generally blackish colour is probably due.

Among other species lepidolite or lithia mica is occasionally found, generally in small quantities, and has as yet been neglected. With the phlogopites, portions which are usually known as cloudy or milky mica occur, but this apparently is of little commercial value.

### *Muscovite.*

Deposits of muscovite are found at widely separated points. They are usually confined to dykes of a whitish pegmatite granite which cut the ordinary gneisses of the Laurentian.

Muscovite in Quebec.

In the province of Quebec this species is known to occur at the following places, and in some of them it has been worked at different times with a certain amount of success.

In the township of Grenville, on lot 9, range VI, first alluded to by Sir W. E. Logan in his report for 1853, where he describes the occurrence of crystals measuring two feet by fourteen inches, specimens of which were sent to the Paris Exhibition of 1855. This deposit has apparently not been worked for many years. Its occurrence is also reported on lot 10, range V, and on lot 1, range X, of the same township, and furthur west in the augmentation of Grenville.

2. In Villeneuve township, lots 31-32, range I, the deposit opened by Mr. W. A. Allan in 1884 was mined for several years. At this place a large dyke of white pegmatite occurs along the bedding of grayish and reddish-gray garnetiferous gneiss which has a strike to the north-east with a westerly dip. This dyke has a width of about 150 feet, and the mica crystals, which are often of large size, occur on the western edge of the dyke, associated with crystals of tourmaline and of

several other minerals. Much of the mica is unfortunately affected by reddish stains of iron which seriously detract from its value, preventing the cutting out of large sized plates. Possibly in consequence of this imperfection the mine was closed some years ago. The associated feldspar in the dyke is often a clear white and has also been mined to some extent for shipment. It is of course possible that the character of the mica may improve at greater depths, but this has never been determined.

3. In Hull township, lot 7, range XII, it occurs in small quantity, but the deposit has never been opened to ascertain the extent. It is possible that other deposits may occur in this area among the pegmatites which are numerous at a number of points, but so far they have not been met with.

4. Along the lower St. Lawrence, in the townships of Bergeronnes, and at a distance of 20 to 30 miles below the mouth of the Saguenay, several deposits of this variety occur and have been opened up to some extent. Some of the crystals are of good size, cutting as much as 7 x 10 inches, though the percentage of this size is small, the average being about 4 x 5 inches. This location is about ten miles inland and was opened about the year 1892. Two mines known as the McGie and the Beaver lake are located here. A similar variety is also found in the townships of Escoumains and Tadousac. About 400 miles below Tadousac at Watsheshoo, muscovite also occurs but the extent of the deposit has not been ascertained.

At Lac Pied des Monts, about 17 miles north of Murray bay, it has been observed, and at Lake Manouan, about 250 miles north of Lake St. John on the portage to Fifth lake it was reported in 1885 by Mr. A. P. Low as occurring in large sheets or crystals with hornblende in a greyish green limestone interstratified with red gneiss.

In Ontario, muscovite occurs at several widely separated points:— Muscovite in Ontario.

1. In Frontenac county, township of Miller, lots 4 and 5, range XI, where it has been mined at intervals for some years. Many of the crystals at this place are affected by iron stainings, and the locality is about 20 miles from shipment on the Kingston and Pembroke railway.

2. Furthur west in the township of Calvin, about ten miles west of Mattawa, one mile and a half north-east of Eau Claire station on the Canadian Pacific railway. The mineral here occurs at several places and has been mined to some extent. The mining was practically confined to an area on lot 19, range IX, but the plates produced seem to have been of small size and the work has been abandoned. The mica

occurs in a large dyke of pegmatite which cuts the gneiss, and a peculiarity noted at this place is the presence of a dark biotite in the same dyke.

3. On the upper Ottawa at a point about five miles above Pembroke on the Ontario side of the river, crystals of muscovite of large size were reported by Mr. A. Murray many years ago, as occurring, on what was then known as Montgomery's clearing, in a large dyke of pegmatite. This deposit has apparently never been opened up and the extent is therefore unknown.

4. At Yeo island, near the upper end of Tar island, one of the Thousand Island group in the St. Lawrence river where the mineral occurs, apparently in small quantity, with tourmaline in a pegmatite dyke. It does not appear to have been opened up and its economic value is probably small.

Among other localities where mica occurs, and has been reported by different observers, though the species is not clearly indicated, may be mentioned the following:—

Lawson, in Report for 1885, states that it is found in rather large quantities in the Lake of the Woods district, notably on Falcon island, in a pegmatite dyke which cuts gneiss and schist, the mica being in large crystals but injured to some extent by films of iron oxide. It occurs also on Sabaskong bay and on Big island, as well as on Rainy lake, the locality first named being the only one at that time worked.

Dr. Robert Bell in 1885, reported the presence of mica as occurring along the shores of Hudson strait, in specimens of good size, but the exact locality was not definitely ascertained, the Eskimos stating that it came from near Kimnirook. Specimens of beautifully clear white mica have also been handed me as coming from some part of the Labrador coast, but no definite information as to the point from which these were obtained was given.

On the shores of Hudson t i t.

Dr. G. M. Dawson reported the presence of mica, species not specified, as occurring in British Columbia, in veins in granite rocks in the vicinity of the north-east arm of Shuswap lake, the crystals being of large size; and also from a point about 120 miles north-east of Clinton.

The Ontario Bureau of Mines reports mica as occurring in the townships of Cleland, about twelve miles south-east of Sudbury, and also in the township of Gladman, about twenty miles north of Lake Nipissing. This mica is apparently of the muscovite variety, occurring in granite.

## *Phlogopite.*

This mineral belongs to the class commonly styled magnesia mica, and in the Geology of Canada 1863, p. 494, it is stated that this variety is usually associated with the limestones of the Laurentian.

Since that early date however, the developments in the mica industry have been great, and the relations of the mica to the contained rocks are better understood. While phlogopite is almost always associated with pyroxenic rocks, which like the pegmatites, cut the containing rocks in all directions, it is very rarely, if ever, found in the limestone portion of the crystalline series. In certain portions of the pyroxenes, however, there occur large masses of carbonate of lime or calcite which form an integral part of the intrusive mass. This calcite varies in colour from almost white to a deep pinkish-red, and must be distinguished as a mineral, from the ordinary limestone formation. It is probable that a lack of proper separation of the limestone from the calcite first led to the statement as to its occurrence in the former. Mica-bearing rocks.

Phlogopite mica is found at many points throughout the Ottawa district, northward and westward in the vicinity of Rideau lake, also in the belt of country north from Sydenham towards Sharbot lake, and in this direction some of the largest mines of this mineral in Canada occur in the townships of Loughborough and Bedford, between the Rideau canal and the line of the Kingston and Pembroke railway. Its mode of occurrence varies greatly in different places, but in so far as yet studied, the deposits may be classed generally under four heads.

1. As contact deposits, usually occurring near the edge of the pyroxene dyke and in close proximity to the associated gneiss which forms the ordinary country rock at most of the mines. The mica in this case follows down along the contact, and very frequently a mass of calcite, either pink or gray in colour is found through which the mica crystals are disseminated. Sometimes the calcite is replaced by large pockets of apatite, and when occurring in these minerals the mica crystals are usually in much better shape for cutting, than when they are scattered through the mass of the pyroxene, being as a rule, less broken or fractured. Frequently crystals of apatite and pyroxene are found in the same calcite mass with the mica, but at times these are practically absent. Crystals of mica are often found with included crystals of apatite, and sometimes with small inclusions of the calcite, these occurrences detracting greatly from the value of the crystals. As in the case of the apatite, mica occurring under these conditions may be found at almost any reasonable depth so long as the conditions Mode of occurrence

for its occurrence are favourable, and in fact mining has been carried down profitably on these contact deposits to a great distance as in the case of the Lake Girard mine in Wakefield township, which reached a depth of nearly 250 feet, in the Stoness or Buck lake mine to a depth on the slope of over 400 feet, and in other places to depths ranging from 100 to over 200 feet. These deep mines were all in contact deposits of calcite which sometimes formed pockety masses of great size. Sometimes the calcite is replaced in depth by apatite as in the Blackburn mine in Templeton township, and the mica occurs in this mineral in the same manner as it does in the calcite. A similar occurrence is seen at the General Electric Co.'s mine near Sydenham, where the calcite in the upper levels, apparently passes gradually into large bodies of apatite in the lower series of workings.

2. In pyroxene near the contact of cross dykes of diorite or pegmatite, the action of which on the former has often led to the formation of both mica and apatite. Numerous instances of this are seen in both the mica and apatite mines, and the crystals of both are often of large size and well formed.

3. In the mass of the pyroxene rock itself, distinct from the contact with the gneiss, the deposit following lines of fissure, often of large size and considerable extent. In this case, though the mica is frequently crushed and broken, large masses of crystals of fine quality and good size are found, the broken nature being sometimes caused by cross fracture and subsequent dislocation. As a rule, the deposits of this class do not appear to be so persistent as in the case of contacts. Some of the pyroxene masses are very large, as at the Cascades mine near the Gatineau, and at the Nellie and Blanche, lower down on the same river. In these cases the calcite is almost entirely absent, and apatite rarely occurs to any extent. When these masses are cut by cross dykes the conditions for both minerals are more favourable, and it is in this connection that the large masses of apatite are found along the Lièvre river. Often in deposits of this class the mica is found in irregular pockets, some of which are workable but in the smaller ones the crystals are often too much crushed to pay for their extraction.

4. In pyroxene dykes which cut crystalline limestone, and through which later dykes of diabase or pegmatite have intruded, as in the Quinn mine in Hincks township. At this place the crystals were of large size, occurring in the pyroxene near the pegmatite, but the mica is usually very darkly coloured, resembling a biotite. This is practically another form of class 2, the difference being chiefly in the character of the country rock.

Throughout both the Ottawa and the Rideau-Kingston districts the association of the mica and apatite is very intimate. There is, however, a marked difference observable in the mode of occurrence at different points. Thus in the area along the Lièvre, including the townships of Buckingham and Templeton in part, the apatite often occurs in large pockety masses in the pyroxene and has in places been worked downward by deep shafts along the contacts with the gneiss to a depth of some hundreds of feet, as at the North Star mine and in some parts of the High Rock group. In these areas mica is rarely seen ; but on approaching the mines north of Perkins Mill, comprising the Jackson Rae, the Blackburn and others around the shores of Wakefield lakes, the intimate mixture of the two minerals becomes very marked. In these areas the apatite is for the most part of the massive variety, while in the Gatineau district it occurs rather in the form of crystals disseminated through the calcite, and the massive form is rarely met with. The mica here becomes the leading mineral occurring in several ways but largely in calcite, while in the Templeton district it frequently occurs with the apatite which here replaces the calcite to some extent. This feature is especially well seen in the Blackburn mine which at one time was one of the largest producers of apatite in Canada, the mica being then regarded as a by-product of but small value, while at the present time the conditions are reversed and apatite which is extracted in mica mining is saved as a by-product, the mica being the mineral of chief importance.

Association of mica and apatite.

As an illustration of the growth of the mica industry it may be remarked that returns from Canadian mines were first published by the Geological Survey in 1886 when the value of the mineral extracted was stated to be about $29,000. This figure was pratically maintained till the close of 1889, when the rapid increase in electrical development opened a new market for the mineral, and in 1890 the value of the output increased to $68,074. This in 1892 was further increased to $104,745, after which there was a gradual decline for several years to 1898, when the demand developed very rapidly and in that year the value of the output reached $118,375 ; in 1899 it rose to $163,000 and the returns for 1901 were about $160,000. The greater part of the output is exported. These figures are taken from the published Report of the Section of Mines of this Department.

Development.

In the province of Quebec phlogopite has been found and mined to some extent in the townships of Hull, Wakefield, Templeton, Buckingham, Portland, Aylwin, Hincks, Northfield, Bouchette, Wright, Alleyn, Cawood, Ripon, Litchfield and Grenville, but the principal mines

are located in the three townships first named. In Ontario the principal deposits are found in the townships of Loughborough and Bedford north of Kingston and east of the Kingston and Pembroke railway in the county of Frontenac; and in North Burgess and North Elmsley in Lanark county and South Burgess in Leeds. Its presence in greater or less quantity is also reported at a number of other points in this province, but so far little mining has been done outside of the Kingston and Rideau districts.

In most of these areas mica mining is subject to considerable fluctuation, owing chiefly to the irregular nature of the deposits in many places. Thus, a very fair surface showing of crystals may indicate merely a pocket, which when worked out often leads to the expenditure of much capital in the unsuccessful search for other masses, and the consequent abandonment of the place for a time. This condition is more often the case with pockety or fissure deposits in the pyroxene, the contact deposits being usually more regular and the conditions appearing to be more favourable.

The percentage of marketable mica obtained from most of the mines is never very large, owing to the fact that many of the crystals are too small or too much fractured or are otherwise too imperfect, to be cut to any but the smallest marketable size. Many of the large crystals are comparatively free from such imperfections but these are sometimes affected by sharp lines of fracture which divide the sheets into long and narrow strips, forming what is known as ribbon mica. Probably the amount of merchantable mica obtainable from the output of most mines will not average more than 10 per cent of cut sizes, so that in estimating profits, a large margin must always be allowed for waste material.

## The Quebec District.

Mines in Quebec.

Of the numerous mines opened and worked at different times in the townships of Buckingham and Templeton, practically the only ones now operated are those known as the Blackburn mine on lots 9 and 10, range XI, of the latter township; the Wallingford mine on lot 16, range VIII; and several new openings near the shores of Battle lake, owned by the latter company. The two first come under the head of contact deposits, the latter are in part contacts and in part fissures.

At the Wallingford mine near Perkins Mills, work has been carried on for some years. The old pit which reached a depth of about 150 feet, was abandoned several years ago, after producing a very large

amount of excellent mica, much of which was in large crystals, and a new pit has been opened a short distance to the south. The country rock at this place is a reddish and gray gneiss with granite, cut by pyroxene dykes which have a general direction of north-east and south-west, with an inclination in places to the south of 70 to 80 degrees. The new pit opened several years ago is now down to a depth of 100 to 120 feet, and the mica is found with green apatite, the latter sometimes in large quantity, along the foot wall of the dyke in a fairly well-defined zone. While a large proportion of the crystals mined are somewhat small, and in parts badly crushed, crystals of large size also occur quite abundantly. The apatite is saved as a by-product, and the price of this mineral, for No. 1 grade, is now said to range from $8.00 to $10.00 per ton. Openings to the south of the main pit on the present worked dyke also show mica and this may represent a contact deposit on the other side of the pyroxene, but the central mass of the intrusion is barren in so far as yet tested. The width of the mica zone now worked on the foot wall is from three to six feet. Calcite is found in small quantity, but in this mine it appears to be in part replaced by apatite.

In the Blackburn mine on lots 9 and 10, range XI, Templeton, some facts were observed. This place has been almost continuously mined for many years, first for apatite, and the two minerals are intimately associated. The workings have been carried down in a large open cut to a depth of about 250 feet with a large drift at the east end. Calcite is sometimes seen, but is apparently largely replaced by apatite in which the mica crystals are abundant, and frequently of large size, some of them cutting 5 x 14 inches, and it is stated that about 30 per cent of the output is saved for the market, which is a somewhat large proportion.

The apatite appears to occupy the north side of the pyroxene, which is in a large mass, the gneiss in contact being seen on the north wall, and the conditions appear quite uniform to the lowest level worked. In the sides and roof of the main cut, and in the long drift to the south-east the mica crystals are thickly studded, often lying solidly packed together in the apatite with which calcite sometimes occurs. The country rock is the usual grayish and reddish-gray gneiss, and the pyroxene dyke cuts across the stratification.

On the north side of Battle lake, in the mine recently opened by the Wallingfords, there is a large mass of the pyroxene cutting the usual character of gneiss with some quartzite. Other smaller dykes of the pyroxene are seen, and in these the mica crystals are developed

along fissures or as small pockets. No calcite is visible in the principal opening, but small quantities of apatite are scattered through the mass. Some of the crystals are of large size, as much as sixteen inches across the face, but the bulk of the output so far obtained, is only suitable for cutting into the smaller market sizes. The pit is, however, not more than 20 feet deep and the deposits may improve at greater depths.

The pyroxene at this place is generally soft, and often filled with small mica scales forming a mica-pyroxene. Where calcite is seen, it follows along thin seams in the rock.

To the north of this in the direction of Lake Rheaume other masses of pyroxene occur cutting the gneiss, in some of which apatite is abundant, sometimes in the form of sugar phosphate, carrying mica crystals; in other places the mica is found in the calcite with masses of apatite crystals after the manner of contact deposits. None of these openings have been developed to any considerable extent for mica, as the mining formerly done was on the apatite.

In the apatite areas adjacent to the Lièvre, such as the High Rock group and those north to High Falls, situated on the west side of the river, mica has not yet been found in quantities of economic importance. In Portland east and in Derry townships on the east side, several deposits have been opened and mined to some extent. The largest of these areas is that owned by the Glen Almond Co., on lots 1 and 2, range I of the former township, where a considerable amount of development has been done and a large quantity of mica, generally of the small sizes, has been obtained. These mines are not at present being worked.

### The Gatineau District.

Mica is found along the course of the Gatineau for at least 150 miles from the mouth, but the principal mining locations do not extend for more than half this distance.

Among the first locations where mica mining was developed in this area may be mentioned the group situated near Wilsons Corner about six miles east of the river near the line between the townships of Hull and Wakefield. The country rock is generally reddish-gray and gray gneiss with occasional limestone bands. Intrusions of pyroxene, pegmatite, hard dark diorite, and gabbro are very frequent. The full descriptions of these areas are given in the report on the Grenville sheet, No. 739 of the official list of publications. The principal points of interest will only be stated here.

Among the mines of this group to the west of Wilsons corner may be mentioned lot 16, range I, Wakefield; lot 12, same range, (Hughes and Haldanes); lot 14, range XVI, (Horse shoe mine), all of which have been abandoned for some years. The mica in these mines occurs usually with calcite and sometimes apatite, in the form of contact deposits in pyroxene near the gneiss.

On the south side of the road, other mines occur which were at one time worked to some extent. These include lot 12, range XVI, Hull, (McLelland's); lot 13, same range, (Wilson's); and lot 12, range XV, (Chubbuck's). At the first named, serpentine is found with the pyroxene and the crystals are sometimes brownish or purple tinted. On lot 13, range XVI, large crystals of amber mica were found, as well as of pyroxene. Most of these deposits are of the contact class, but no work has been done on these properties for some years.

To the north of Wilsons corner, mica has been worked on lot 14, range II, Wakefield; lot 16, same range, (Chubbuck and Wilson); lot 18, same range, (Seybold's); in all of which the deposits are of the contact class, the only locality at present worked being the second named.

The deposit on lot 16 was first opened in 1892-93 and examined in the latter year by the writer. Since that date a large amount of development work has been done, principally under the direction of Mr. Chubbuck of Ottawa, and the following remarks as to its present condition may be made. The property is now known as the Kodak mine and as an illustration of the character of contact deposits its study is interesting.

The mica occurs along the contact of a large dyke of green pyroxene with the grayish gneiss, and is associated with a mass of pink calcite which has a thickness varying from three to fourteen feet. In this respect the conditions are very similar to what were seen at the Lake Girard mine, for some years one of the largest producers of mica in the Ottawa district. The mica crystals are generally found in the part of the calcite adjacent to the pyroxene, but sometimes in the outer portion of the pyroxene itself, and the deposit has been opened up along the line of the outcrop for a distance of some 600 feet, by a series of eight or ten pits with depths varying from 15 to 50 feet, and by a shaft to a depth of 150 feet. Many of the crystals are of large size and excellent quality, occurring in pockety bunches or masses which are continuously exposed to the bottom of the shaft. The character of the deposit appears to be fairly uniform throughout its entire development along

the line of strike, and the masses of crystals have a thickness in places of from three to six feet.

The mine is well equipped with an electric plant for lighting and for pumping, which is driven by water power obtained from Blackburn creek which crosses the property and is sufficient for all purposes of development. The mine has produced a large quantity of excellent mica during its period of working. This is roughly dressed at the surface and then hauled to Ottawa where it is trimmed and prepared for the market. This mine, with that known as the Nellis mine on lot 10, range XI, Hull, are two of the most important in this district.

To the south, on the road from Wilsons corner to Ottawa, several mines are located, including lot 10, range XI, Hull, (Gemmill or Nellis); lot 10, range XIV, (Webster's old mine); lot 1, range XIII, (Burke's); lot 3, range XIII; lot 9, range X, (Nellie and Blanche); these are all of the contact class except the last which is a fissure deposit. Of these the Nellis mine has been worked for some years almost continuously and has been a large producer of very excellent mica.

Nearer the Gatineau is the Cassidy mine on lots 15-16, range XV, Hull, a fissure deposit worked for some years, but also abandoned after producing a large amount of mica, some of which was in large and fine crystals; and the Macfarlane mine to the north which is a contact deposit opened to some extent, but like many others in the district abandoned.

West of the Gatineau river.

West of the Gatineau, and near Kingsmere, the following mines are located in the township of Hull. Brown's mines on lot 19, range VII, Hull; Fortin and Gravel on lot 18, and the Fleury mine on lot 20 same range. The rock at these mines is reddish and gray gneiss with bands of crystalline limestone, and numerous dykes and masses of pyroxene occur. At all these mines the mica occurs as contact deposits with bunches of calcite and some apatite, the latter as crystals, and the mica is sometimes in large clear crystals. The Fortin mine has been worked to a reported depth of nearly 100 feet.

On the road from Old Chelsea to Kirks Ferry, the Scott mine is on lots 14 and 15, range IX, not worked for the last ten years, and on lots 15 and 17, range X, several openings have been made on small surface showings of mica which have never been worked to any considerable extent.

Near Kirks Ferry, on lot 12, range XI, (Haycock's), some mining was done about ten years ago, and on lot 14, range XI, (Connor's), a number of openings were made about the same date, with fair surface

showings at different points. The uncertainty of these deposits was apparently the cause of their abandonment.

On lot 23, range XI, (Moore or Wright mine), a short distance above Cascades, there is a large mass of pyroxene, from which considerable mica was at one time obtained from fissure deposits. But little calcite or apatite was observed in any of the openings near this place, which are made over a large area.

Township of Low.

Further north, in the township of Low, lot 36, range XIII, is the Venosta mine, from which some large crystals were at one time obtained, but which has been closed for ten years or more. In Hincks, lot 22, range II, the Quinn mine, worked by Powell and Clemow about ten years ago, produced a considerable quantity of large dark coloured mica and was then abandoned. In Wright township, lots 14, range D, the Guay mine was an extensive producer for several years and reached a depth of nearly 100 feet, the output being of excellent quality. At this depth the mica is said to have become exhausted. This was a good illustration of a contact deposit. In the township of Bouchette, lot 31, range I, a large deposit of mica in pyroxene cutting gray and rusty gneiss was worked for a time, but the mineral was of the dark variety, and the mine has been abandoned for some years. Most of these mines were on contact deposits.

Templeton and Portland.

Around the Wakefield lakes in the townships of Portland west and of Templeton, several apparently large deposits were operated some years ago. The remoteness of the mines from the railway necessitates expense in shipment and no work has been done in this area for some years.

Among the principal mines in this district are the McRae, on lots 26-27, range IV, of the former township, the mica occurring in pink calcite with both red and green apatite; the Laurin mine, lot 20 range XII, Templeton, and the Templeton and North Ottawa Co., lot 21, same range. In all these places the mica is closely associated with apatite and there are numerous intrusions of pegmatite and pyroxene in the red and gray gneiss. No work has been done on these areas for some years.

Among other localities in which mica occurs, north of the Ottawa and west of the Gatineau, may be mentioned the township of Huddersfield near the outlet of Moose lake, where a hard pyroxenic dyke cuts gneiss and carries a small amount of dark mica with pink calcite. Attempts to mine this profitably have not yet been successful. In Litchfield, lots 20, 22, 23, range IX, several miles in rear of Camp-

bells bay a quantity of dark mica has also been found, apparently not of good quality as but little attempt has been made to work the deposit.

Similar small deposits have been found in lots 7-8, range A, Waltham.

Pickanock area.

Near the Gatineau in Wright, about one mile south of the Pickanock river, close to the post road, is Moore's mine with a fair showing of small sized crystals, which has been opened to some extent, and further south on lot 6, range A, a deposit opened up by Mr. T. J. Watters some years ago, has been taken over by the General Electric Co., under the name of the Shibeer mine and is now being developed with a diamond drill and by shafts with promise of a large output, as the mica has improved in depth. These are both contact deposits. On the east side of the river in Northfield, lot 3, range A, a Toronto company opened some pits several years ago on dykes cutting gray gneiss, but the output was generally of small size and work was soon stopped. Another opening was made on lot 13, range B, in the same township, but little mining was carried on.

In the township of Alleyn, near the Kazubazua river, on lot 10, range II, a large deposit of excellent mica has been worked by Mr. Joshua Ellard of Wright post office. The country rock is a gray gneiss with limestone, cut by pyroxene, and the mica is found in calcite as a contact zone of two to three feet in width. Several hundred tons, of excellent quality, have been extracted.

Openings have also been made on lot 12, range I, in calcite, but the mine has not been worked for several years. On lot 4, range II, on Mrs. Mullingham's property, operated in 1898-1900 at intervals, the pyroxene traverses a red granite and the mineral occurs with a little apatite and calcite.

In the township of Cawood, lots 23-24, range III, some good and nearly white mica was obtained in 1897, and the pit was worked for a short time in the following year. On lot 41, range V, about 20 miles north of Shawville, a small quantity of good amber mica was obtained in 1898, but nothing has been done recently.

On lot 12, range VI (Priestly mine), some exploratory work was done on pyroxene cutting a gray granite and a small amount of amber mica was obtained.

On lot 18, range VI, (Brock and Pritchard) a deposit was worked for a time at intervals in 1898-99. Some good crystals were obtained

but nothing has apparently been done recently. The country rock at this place is largely a red granite cut by pyroxene, carrying calcite.

Mica is also reported from lots 17 and 22, range VII, Low township and from lot 53, range VII, Aldfield. Also from lot 14, range I, Clarendon, and from lot 51, range III, Thorne, from which several tons were taken.

Among the largest and at one time, most important of the mica deposits in the Gatineau belt is the Lake Girard mine on lot 24, range II, Wakefield. As an illustration of a contact mine it may be specially mentioned.

The country rock here is grayish and reddish-gray gneiss with several bands of crystalline limestone. About 120 paces back from the shore of the lake a large dyke of pyroxene cuts across the gneiss, and on this the mine is located along the foot wall or contact. The excavation has been made to a depth of about 250 feet, and large masses of pink calcite are found in the margin of the pyroxene through which the mica is disseminated in large pockets of crystals, some of which are of fine quality as regards size and clearness. In places, however, the calcite is quite barren. But little apatite was found in the mine, and at the lower levels the mica disappeared, the calcite forming large masses. This disappearance of mica in calcite when the latter reached large proportions has been noticed at several other places. It is possible that along other parts of the contact similar large deposits of mica occur, but at present the mine is closed.

In addition to the above descriptions which comprise the principal depo its in the area north of the Ottawa, mica has been found at a number of other points which may for the sake of reference be mentioned.

Mines in Templeton.

In Templeton township, in addition to those already stated :—

Lot 21, range IV, indications only. (McTierny).

Lot 22, range IV, (Taylor and McVeity), an old apatite mine, reopened for mica in 1898, and a considerable amount extracted.

Lot 20, range V, (W. Smith). Indications.

Lot 10, range VII, (Stevenson mine), worked in 1899, by Mr. J. Asquith of Ottawa, by a surface trench which is said to have yielded a large quantity of good mica.

Lot 14, range VII, (American Mica Co., Boston).

Lot 15, E. 1-2, range VII, worked in 1891 by Hon. C. A. Dugas, in 1896-97 by Baumgarten and Manchester, and later by the Webster Co., to a depth of 50 feet. Some good mica was obtained.

Lot 15, W. 1-2, worked by several parties since 1893; and in 1897-99 to a depth of 70 feet. Reported to have produced a large quantity of excellent mica, some of it of large size.

Lot 4, range IX (Sophia mine), worked at intervals since 1892, producing a large amouut of good merchantable mica.

Lot II, S. 1-2 (North Templeton and Ottawa Mining Co.), prospected in 1894; no information as to results.

Lot 13, same range; indications.

Lot 14, same range. Worked for apatite twenty years ago, and since 1894 for mica, which occurs with the apatite and pink calcite. In 1899, worked by Jurkowsky and Co.

Lots 16-21, also prospected by same company; no returns.

Lot 7, range X, prospected in 1900 by McLauren and McLaren.

Lot 8, same range (Marsolais mine). Formerly worked for apatite, but since 1897, has been worked at intervals for mica, of which a considerable amount has been taken out.

Lot 9, E. ½, (Post mine, Canada Industrial Co.) formerly worked for apatite, but recently for mica, some crystals of large size being found.

Lot 9, W. ½, (Jackson Rae mine), formerly worked for apatite, but since 1892 has yielded a considerable amount of mica. Some of it of good size.

Lot 10, N. ½, (Jubilee mine), formerly worked for apatite, but like the last contains mica in considerable quantity in association.

Lot 10, E. ½, contains both apatite and mica.

Lot 15, W. ½, both mica and apatite; small quantity produced.

Lot 16, (Victoria mine), opened in 1899 by McLaurin and McLaren for 300 feet in length by 60 feet in depth, and has produced a large amount of apatite and mica of excellent quality.

Indications of mica are found, but apparently not yet developed, on lots 12, 13, 14, 24, 27, range XII, and on lots 3, 4, 5, 13 and 17, range XIII, as also on lot 38 of the Gore.

In the township of Hull, in addition to those already mentioned, are the following, some of which have been opened and worked.

Lot 23, range XV, (Ferguson mine), opened in 1899 by Mr. Flynn, a contact deposit in calcite and pyroxene, which has yielded a fair amount of medium and small seized mica. Mines in township of Hull.

Lot 25, range XV, (Moore mine.)

Lot 27, range XVI, (Gorman mine) opened in 1898 by Mr. Bishop of the Cascades, has been worked at intervals, for some time.

East of the Gatineau river are the following.

Lot 7, range X, (Foley or Big Crystal mine) closed since 1898.

Lot 5 and S. ½ lot 6, range XI, (Kearney mine) worked in 1892 by Rae and Allan. The Eureka mine on lot 6, same range, worked in 1893 by Mr. Perkins.

Lot 12, north ½, range XV, (Dacey mine), worked in 1898-99 by Webster & Co., to a depth of about 50 feet with a considerable output of rather small mica.

Lot 13, south ½, same range, opened and worked as an apatite mine, but reopened in 1893 by Clemow and Powell for mica.

Lot 13, north ½, James Connors, worked by Webster & Co. in 1892 and by the owner in 1899. Small quantity only reported.

Lot 15, east half, same range, (Jameson mine), worked for several years to a reported depth of 75 feet; some mica of large size obtained.

In the township of Wakefield mines exist in addition to those already mentioned on :— In Wakefield.

Lot 15, range II, (Comet mine) worked in 1898-99.

Lot 16, same range, (Kodak mine) formerly Chubbuck and Wilson, worked to a reported depth of 110 feet along a distance of 200 feet, from which a large quantity of good mica was produced, and in 1900 also worked for a time by Jurkowsky & Co. and by Webster & Co.

Lot 17, range II, (Morris mine) opened in 1892, has produced some very large mica.

In the township of Portland west : In Portland.

Lots 12 and 13, range III, (Lake Terror mine).

Lot 15, same range, opened in 1900, produced a small quantity of good mica.

Lot 24, N. ½, (Lila Mining Co.) worked in 1899 as an old apatite mine which yielded also some fine mica crystals.

Lots 26, 27, 28, range IV, (Fleming and Allan), once mined for apatite, were reopened in 1891, and produced a considerable quantity of good crystals.

Lots 5-6 (McIntosh mine), formerly worked for apatite, has also yielded some mica, quantity unknown.

In the township of Portland east:

Lot I, range I, (Judge mine) opened first 1893, reopened 1899, area adjacent to the lots of the Glen Almond Co.

In Derry the Glen Almond Co. has done some mining on lot 23, range II, and on lots 3, 4, 6, range III.

Lot 9, range I, opened by W. A. Allan in 1900, a few tons taken out from surface workings.

In Buckingham, lot 25, north ½, range IV, mined in 1899 by Mr. Tetreau and in 1900 by Mr. D. Richard. Some small mica obtained.

South March mines.

In the area south of the Ottawa, near South March station on the Canada Atlantic railway, and to the north-west of Carp station several deposits of mica, with which is associated small quantities of apatite, are found. The country rock is the usual gray and red gray gneiss which is cut by masses and dykes of a hard dark gabbro or pyroxenic diorite, in which the mica occurs. The crystals are sometimes of good size, but very-dark coloured like a biotite, and usually hard and somewhat brittle. This renders them practically of little use for cutting into thin sheets, but when weathered for a time they become more elastic. But little economic importance has as yet been attached to these deposits by dealers in mica, and work has been suspended for some years.

## The Perth District.

North Burgess township.

The mica mines in this district are for the most part confined to the townships of North Burgess on the north side of the Rideau lake and to South Burgess, on the south side. The rocks are of the usual type of grayish and reddish gneiss with quartzite and bands of crystalline limestone.

In the former township the occurrences of mica are numerous, and some of the deposits are extensive and valuable. Most of the areas were originally mined for apatite, and very full descriptions of a number of lots on which the minerals occur are given in reports by Mr. Gordon Broome, 1870-71, pp. 316-321, and by Mr. H. G. Vennor,

1873-74, pp. 110-139. From these descriptions it would appear that in nearly all the lots there mentioned fron nos. 1 to 13, on ranges IV to IX, the association of mica and apatite is very intimate, though at the time of these reports but little attention was paid to the former mineral. From the presence of pyroxene dykes which cut the gneiss, and the occurrence of pink calcite at most of the openings it may safely be inferred that the greater number of these deposits occur as contacts. The apatite is found sometimes in the form of crystals disseminated with the mica in the calcite, and sometimes as irregular pockety masses, which were called veins, along the outer margin of the intrusions.

Some of these mines were opened nearly forty years ago, and a large amount of apatite was extracted prior to 1890. The mica being regarded as of but small value, owing to the lack of a market, though several deposits of this mineral were even then worked for a short time to a limited extent. The small demand for mica did not apparently warrant the expenditure of much capital in the development of this industry; but about fifteen years ago attention was turned in this direction and since that time a number of mines have been opened, some of which have proved fairly profitable, though, owing to the uncertain nature of the deposits, many of them have been abandoned entirely or are worked at irregular intervals.

Among those which may be mentioned as occurring in the Rideau-Perth district in the township of North Burgess are the following;— Mines in North Burgess.

The Hanlan mine, now a part of the General Electric Co's system, lot II, range VI, the mica occurring in apatite or calcite the former often iron-stained; a contact deposit. The country rock here is a grayish and reddish-gray quartzose gneiss which is cut by a number of pyroxene dykes with a general course of N. 15° 20° E., varying in width from 4 to 10 feet. About 150 yards west of the present main pit a number of old openings are seen from which small quantities of mica have been obtained. These workings are all shallow. The old Webster pit is about 300 yards south-west of the present workings. In most of the openings calcite and a small quantity of apatite can be seen and they are all clearly contact deposits.

At the pit now being worked by the General Electric Co. a shaft has been sunk to a depth of about 100 feet near the under side of a large dyke of pyroxene, which has a general course of N. 40° E. From the foot of the shaft a drift has been run along this foot-wall in the direction of an open cutting which lies to the north-east. The width of the mica-bearing zone at this place appears to be from 5 to 8 feet

and the crystals are disseminated in calcite which increase in volume below the 60 feet level. Many of the crystals are large and clear, ranging in size up to 14 × 18 inches on the face. The mica from the upper portion of the mine is usually of the smaller sizes, so that the quality improves as lower workings are reached. The area has been proved by diamond drills and the mica found to be continuous in depth. Apatite crystals occur with the mica in the calcite which varies in colour from a creamy white to a deep pink. This mine is a fine illustration of a true contact deposit. Coarse grained, somewhat purple and greenish-gray gabbro dykes cut the quartzose gneiss in the vicinity of the mine as well as on the lot adjacent to the north, where also the calcite appears in considerable volume and is being proved with a diamond drill. Red granite masses are frequently seen, all of which are newer than the crystalline limestone of the area, which overlies the gneiss. The output is hauled to Perth, nine miles distant, and the mine is well equipped with a hoisting and pumping plant, as well as drills.

This mine is the only one in active operation at the present tima, in this district.

Lot 13, E. ½, range VI, (The Martha mine) was worked for some time with shafts to a depth of 100 to 130 feet.

Lot 11, range V, (the Baby mine), was also worked by shafts to a depth of 130 feet.

Lots 11 and E. ½ lot 12, range VII, (Byrnes mine) worked some years ago to a depth of about 80 feet.

Lot 4, range VI, (Watts and Noble mines).

Lots 16-17, range IX, (Pike lake mines), said to be the oldest mica mine in Ontario, was worked by several shafts from 55 to 90 feet deep. This mine is in a large mass of pyroxene and seems to belong to the class of fissure deposits rather than to the contact variety.

Lot 10, range V, (Blackhall mine).

Lot 21, range VI, (McNally mine).

Lot 12, range VI, (Old Adams mine).

Lot 4 range VIII, (McLaren mine), worked for both apatite and mica.

Lot 12, W. ½ rang VI, (Munslow mine) adjacent to the Martha,

Lot 16, range V, (Donnelly mine).

Lot 7, range VIII, (Adams mine).

The Noble Bay group of mines is situated near the shore of Rideau lake, and comprises lots 2, 3, 4, 6, 7, 8, and 9, range V; lots 7 and 23, range VI; and lot 24, range IV. Considerable surface mining has been done at several points, but all are for the present abandoned. In so far as examined the pockets are somewhat irregular and the mica is of the smaller sizes.

From the descriptions given by Mr. Vennor of many of the mines mentioned above it would appear that the greater number may be classed as contact deposits. In the vicinity of Otty lake, where several of these are located, the mica does not appear to occur in such well defined masses as in other areas to the west, the apatite having the larger development. It is of course possible that deeper mining would establish the presence of larger bodies of mica at lower depths, as has been found to be the case in other places, but this is a matter for underground exploration and the judicious expenditure of capital. In all mica mining there appears to be a large element of uncertainty as to the continuance of mining conditions, and small companies with limited capital are rarely in the position to obtain the best results as to the extent of the mica deposits in any area. In several cases mines which have thus been abandoned through lack of capital have been opened under different management and proved to be good producers, as the conditions frequently change for the better as well as for the worse.

South Burgess.

On the south side of Rideau lake, on lot 1, ranges III and IV, South Burgess, there is also an interesting development of mica. This was worked quite extensively some years ago under the name of the Cantin mine, and when examined in 1896 had a depth of 100 feet in the principal opening, the mineral occurring as a true contact deposit in calcite, from which large quantities of excellent crystals were obtained. At this depth, however, the mica zone was cut off by a mass of red granite, and after some time spent in a search for its continuation the area was abandoned. Whether the cut-off was due to a fault or to a later intrusion of the granite could not then be ascertained. This property has recently been acquired by the General Electric Co. which proposes to develop the area by means of a diamond drill, in order to ascertain this point.

The country rock at this place includes large areas of crystalline limestone which are cut by both granite and pyroxene. In the dumps there is a large quantity of pink calcite.

On this side of the lake also near the head of German bay, several openings have been made on pyroxene-mica dykes which cut red and gray gneiss, but the mica showings are small and the development work is limited. Along the shores of the lake also several shallow pits have been sunk in similar rock but without showing workable mica.

On the north side of the lake on the east side of Bass bay, the rocks are gneiss and quartzite with red granite cut by dykes in the usual manner, and a number of small openings have been made and some small mica extracted, but work has been suspended here for several years.

As a general statement therefore, it may be said that in the Rideau district the greater part of the mica occurences may be assigned to the contact class. As a rule the rocks are practicaly the same as seen in the Gatineau area, with which the rock formations are continuous beneath the overlying Palaeozoic formations and the conditions for mica are practically the same in the two districts.

## The District North of Kingston.

Mines of the Kingston Rideau district.

In this district may be described several widely separated mines which occur mostly in the area between the Rideau canal and the Kingston and Pembroke railway. They are found in the Townships of North and South Crosby, in Bedford and Loughborough. Some of these were originally mined for apatite, but on the closin of that industry were reopened for mica and have for several years produced large quantities of very excellent quality. The country rock in all cases is the ordinary gray and reddish-gray gneiss with occasional masses of quartzite and bands of crystalline limestone, with which are associated red and sometimes gray granite and pegmatite, while pyroxene is abundant in many parts of the area. The formations are similar to those north of the Ottawa already described.

On lot 14, range VI, South Crosby, is McLaren's mine. This lot was opened up about 20 years ago for apatite and worked for a short time. In 1900 it was reopened for mica. The surface rock about the mine is a hard dark-gray or sometimes blackish diorite with pyroxene, but the usual rock of the ridge on which the mine is located is a reddish-gray granite and gneiss.

On following down the apatite it was found to become associated with mica in considerable quantity, the width of the deposit ranging

from 8 to 10 feet in places near the west side of the pyroxene dyke. Much of the mica seen at the time of our visit in 1901 was in large-sized crystals, some of them measuring 12 x 16 inches but somewhat dark in colour. In places bunches of pyrite came in near the edge of the dyke and when in contact with the mica the latter became rotten and discoloured. The pyrite sometimes passes into a red haematite. Small bunches of pink calcite are found with the mica and both red and green apatite in small amount at a depth of 20 feet which was that of the pit when we examined it. Though a considerable amount of mica was extracted, the mine has since been closed. The occurence of the pyrite at this place and its injurious action on the mica is an interesting circonstance.

Opinicon lake.

Near the line between the townships of Storrington and Bedford on the north side of Opinicon lake are the Smith and Lacey mines which have been extensively worked at intervals for several years. The mica is of a light amber colour occuring in pyroxene dykes which cut a gray and sometimes rusty gneiss, and is associated with a light green mineral resembling a feldspar, but no pink calcite was seen. The mica appears to occur as fissure deposits near pegmatite intrusions, and a large amount has been taken out, much of it of large size and good quality. At the old apatite mine on the east side of this lake, near the outlet from Crow lake but little mica was observed. Along the shores of Rock lake also small shows of mica have been reported but nothing has been done in this direction.

Buck lake, Bedford.

On Buck lake, which is about four miles west of Opinicon lake, there are several mica mines, one of which was worked for a number of years and has been a large producer. This mine is on lot 3, range XII, Bedford, known as the Stoness mine, and belongs to the contact class, the mica being in pyroxene which cuts the grey and reddish gneiss. There are a number of these dykes in the vicinity. Crystalline limestone occurs abundantly on the shore of the lake near the mine and is cut by white pegmatite. The pyroxene in which the mine is located is a light green variety with great masses of pink calcite, through which the crystals are disseminated, sometimes in pockets of large size, and the dump from the mine is largely of this calcite with masses of the light green pyroxene.

The workings were carried on by means of a shaft or slope sunk to the north-west for about 400 feet at an angle of about 30 degrees, the general strike of the gneiss in the vicinity being N. 30° E. A heavy dyke of dark diabase cuts across the gneiss and pyroxene a short distance west of the main opening with a thickness of about 15 feet which was

passed through in sinking the slope. In the workings, large masses of pink calcite were encountered, occurring after the manner of the great apatite pockets in the Ottawa district. The diabase dyke cut off the mica zone which was however resumed after passing through the intrusive mass. The pyroxene cuts the gneiss at a rather sharp angle. In several of the other dykes mica with calcite was found, but in some, no calcite was visible, in which case the mica is in the form of fissure deposits, occasionally in considerable quantity, but often ending abruptly in small fissures with crushed crystals. Sometimes the mica terminates abruptly through the agency of later diabase intrusions.

In the area between the foot of this lake and the road along the shores of Clear and Devils lakes pyroxenes were observed at a number of points, some of which have not been developed to any extent. The calcite at the bottom of the deep shaft is reported to have become almost barren of mica, resembling in this respect the Lake Girard mine, and the quantity of the calcite was such as to be excavated into large chambers.

Tett's mine, Bedford.

Another interesting mine in this area is that on lot 4 range VIII, Bedford, know as Tett's mine. Here the country rock is a grayish and rusty gneiss with some limestone, having a strike of N. 60° E. with a dip to the north-west. This is cut across at an angle by a heavy dyke of light green pyroxene which is, in turn, cut by a very hard grayish-green fine grained granite. The mine is opened by a series of pits along the course of the dyke. In most of these there is no showing of the calcite, but in a couple of the eastern pits there is a small quantity. The mica occurs at or near the contact with the rusty gneiss and large crystals of pyroxene as well as of mica are found.

Iron pyrites occurs in bunches, as at the McLaren mine in the harder portions of the pyroxene and has adversely affected the mica, making it rusty in places. The course of the intrusion is N. 55° E. as indicated by the line of pits, but owing to most of these being filled with water at the time of our visit, in 1901, the conditions of the lower workings could not be studied. Most of the mica extracted had been removed, but the output is reported as of large size and good quality. A small band of impure limestone is seen along the south side of the openings and small quantities of apatite were observed at several points.

Further to the north-west on the shore of Mud bay which is an arm on the north side of Bobs lake, on lot 30, range VI, Bedford, a somewhat important deposit is now being mined by Mr. Stoness and others,

on what was formely known as the Taggart mine. There is here an extensive development of pyroxene cutting grayish-red gneiss with granite masses. Some portions of the former are hard and dioritic, others are soft and light green. A number of openings have been made at this place, and the new developments were commenced in the summer of 1903. The mica veins are exposed along a general course of N. W. and S. E. and are for the most part eitherpockety or fissure deposits. In places the mica zones have a thickness of three to four feet but others are much less. There is no calcite as a rule, but apatite is found in small quantity in the largest opening, which in Sept., had reached a depth of 30 feet and was about 40 feet in length, the mica following along the north side of a hard pyroxene rock, in which the softer portions carried the crystals, generally of small size, cutting 4 x 6 inches and less, the larger sizes being in irregular pockets. The mica is a rather dark amber, but comparatively free from imperfections.

On the opposite or northern side of Mud bay there is a considerable development of crystalline limestone and gray gneiss, cut by pyroxene, in which deposits of apatite were quite extensively mined some years ago.

On lot 2, range V, Oso, near the head of Crow lake, several openings have been made in pyroxene dykes which cut the gneiss at a sharp angle. The principal openings are on a dyke about six feet wide and the mica occurs on the west side in deposits of calcite. Apatite occurs also in small quantity, and the locality was at one time worked for this mineral.

The general course of the dykes is about N. 15° W., with a dip sometimes to the west and sometimes to the south-east. The mica vein in the principal opening is disclosed for about 50 feet in two pits but a good deal of the mica is crushed. About 150 feet west of this opening another smaller dyke has been opened and a similar occurrence of mica can be seen. These are both good illustrations of contact deposits. Further to the east mica also occurs under similar conditions, but no work has been done here for some years. The output from the Bobs lake mines is hauled to Olden station on the Kingston and Pembroke railway.

Loughborough mines.

In the vicinity of Sydenham lake and on several of the lakes to the north, there are a number of interesting mica deposits, among which the largest and apparently most important is that known as the old Smith and Lacey, now the property of the General Electric Co. of Schenectady. The mine in on lot II, range VII of the township of Loughborough.

General Electric Coy's mine.

This mine is noted for the size and excellent quality of the crystals extracted, some of these having dimensions of over seven feet in length and one has been found of over nine feet in length.

The knoll on which the mine is located is rather more than a fourth of a mile from the east side of the narrows which connect Sydenham lake with Eel lake, and is intersected with dykes of pyroxene, some of which are large. The principal workings at present are on the north side of a large dyke which has a general course of north-east, cutting at an angle across the country rock which here is a brownish or gray mica gneiss, associated with crystalline limestone which shows in a large body to the south. The strike of the gneiss is about N. 30° E. and the dip to the north-west.

The pyroxene at this place varies in character, some of it being light-green, soft and filled with small mica scales; other parts are hard and dioritic, altering in places to a true pyroxene. In the main pit of the General Electric mine, the mica, which is on the northern side of this intrusion, occurs in a soft portion of the dyke which passes down into the hard dioritic mass in which the mica is absent. The crystals are associated with large masses of calcite varying from pink to gray, but the mica zones are large and generally along the course of the dyke wall, forming a well defined contact deposit, with side veins which are of the nature of fissures.

The width of this dyke has not yet been definitely ascertained. Where the mica is found on the northern edge, the dip of the contact is north at an angle of eighty degrees. In part the mica is mixed with a white calcite but at about 115 feet down this calcite is largely replaced by green apatite in which the crystals are found, and in places both the calcite and apatite are intimately associated. In another part of the deposit the mica occurs in the pyroxene as side veins without either calcite or apatite, probably indicating fissures from the main mica zone, which trend to the south or centre of the dyke.

At the west end of the mine the pyroxene is heavily mineralized with pyrite, and the rock is crushed and slaty and shows the presence of slickens, indicating a fault in this direction by which the pyroxene is probably cut off. At the surface the ground here is low and swampy. A patch of gray Potsdam sandstone occurs a short distance to the west with an area of 60 by 30 yards, resting on gneiss.

The mine is well equipped with a mining plant, for hoisting, drilling, &c., and is worked by a series of levels from a main hoisting shaft which has a present depth of over 160 feet. The drilling is done by

compressed air, and a fine ladder-way forms a convenient means of access to all the levels.

Mode of occurrence of cystals.

The occurrence of the mica crystals, often of immense size is interesting. They are found sometimes in the calcite, sometimes in the apatite; and occasionally the enclosing substance is a mixture of these two minerals. In one of the calcite masses are large crystals of pyroxene of at least six inches diameter. One crystal of mica was removed with a length of over nine feet and a breadth of from four to six feet, the quality of which was excellent. Great numbers of smaller sizes, occur an the output generally is of extra large dimensions, the crystals being in great masses, and some of the individuals weighing several tons.

Of the many smaller dykes which intersect the surface of the knolls in this area, some are soft and filled with small mica scales, others are hard and dioritic, and a passage from one to the other is sometimes exposed on the adjacent lot to the south, where several openings have been made, but here much of the mica, while of fair size, is cloudy or milky and of small value.

The mica zone at the main pit is in places from 12 to 18 feet wide, and is bounded on the south by a hard blackish diorite or a hornblende granite which sometimes assumes a reddish tint. To the east of this main pit are a number of smaller openings, some of them test pits, in a soft micaceous pyroxene in which the mica crystals are often cloudy. About 50 yards to the north are the workings of the old Smith and Lacey mine, which was also a true contact deposit and which for several years produced a considerable quantity of very large mica, but this portion of the property is now filled with water so that the old workings could not be examined. As the present mine is well developed the output should be very great and of superior quality as regards size. It is all shipped to the cutting plant of the company in Ottawa.

Other mines.

Among other mines in this district, most of which are not now worked, is one on Gould lake, operated by Mr. Fralick of Sydenham. The place was not visited, but the owner says the rock is the usual type of reddish and sometimes garnetiferous gneiss, overlaid in part by crystalline limestone, and cut by basic dykes of pyroxene. The mica occurs for the most part as contact deposits, between the gneiss and the dyke or between the dyke and the limestone, and sometimes in the mass of the pyroxene itself, in the first case along the foot wall in calcite. The vein is somewhat irregular in places, varying, as usual, in productiveness in different parts of the mine. No details as

to output or plant are to hand, but work is now being carried on, and the principal pit is down to about 50 feet.

From an examination of so many widely separated localities, it is evident that the occurrence of mica is practically the same as regards conditions throughout the whole area. In many places the only examination possible was from the surface workings, as owing to the pits being closed or filled with water, it was impossible to see the relations of the mica with the enclosing rock formations in the lower portion of the workings. Where access was possible, however, the mines were examined throughout, and the geological conditions ascertained.

The purple or lithia mica is not often found in this area and is not an article of commerce. It occurs usually where the crystalline limestone is intersected by white pegmatite dykes. An illustration of these is seen in the township of Wakefield, near Lascelles post-office and also on lot 6, range IV, of the same township. There is not sufficient mica of this variety in either place for economic mining, but the localities are interesting as mineral occurrences. Another locality for this variety is near Wilsons Corner on lot 11, range XVI, Hull.

NATURAL SCIENCE
TN
226
A3
1903
v.9

✓ 872

GEOLOGICAL SURVEY OF CANADA
ROBERT BELL, M.D., D.Sc. (CANTAB.), LL.D., F.R.S., I.S.O.

# MINERAL RESOURCES OF CANADA

## BULLETIN

ON

# MOLYBDENUM AND TUNGSTEN

BY

R. A. A. JOHNSTON

WITH NOTES BY C. W. WILLIMOTT

OTTAWA
PRINTED BY S. E. DAWSON, PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1904

No. 872.

THE UNIVERSITY OF MICHIGAN LIBRARIES

Natural Science
Library
TN
226
.A3
1903
v.9

# MOLYBDENUM AND TUNGSTEN

By R. A. A. Johnston.

## MOLYBDENUM.

Ores of Molybdenum.

Molybdenum is an essential constituent of the following minerals :— molybdenite or sulphide of molybdenum; molybdite or molybdic oxide : wulfenite, molybdate of lead or yellow lead-ore; powellite, molybdate and tungstate of calcium; belonesite or molybdate of magnesia; ilsemannite, supposed to be a molybdate of molybdic oxide. Of these molybdenite and molybdite are the only ores of molybdenum which have so far been reported as occurring in Canada. They form the source of by far the greater portion of the molybdenum of commerce, molybdenite being the more important of the two. As for the other ores of molybdenum mentioned above, wulfenite alone has ever attained any economic importance and that only to a very limited extent, the supply being so small and uncertain as to be almost inconsiderable. The remaining ores do not possess other than a purely scientific interest.

Molybdenite, free from impurities, contains 60 per cent of molybdenum and 40 per cent of sulphur. It occurs sometimes in tabular hexagonal crystals, but more often in foliated masses. It is a soft sectile mineral with a hardness of 1 to 1·5 and a specific gravity of 4·7 to 4·8. It has a pure lead-gray colour and metallic lustre. On white paper it affords a bluish-gray streak and on porcelain a slightly greenish streak. Before the blowpipe, it is infusible but imparts a yellowish-green colour to the flame. On charcoal the pulverized mineral gives, in the oxidising flame, a strong odour of sulphur dioxide, the coal at the same time becoming coated with crystals of molybdic oxide, which are yellow while hot and white after cooling. This coating acquires an azure-blue colour if touched intermittently with the reducing flame. Molybdenite is decomposed by nitric acid with separation of a white or grayish-white residue of molybdic oxide.

Means of identifying molybdenite.

Previous to the year 1778 much confusion existed as to the identity of molybdenite and graphite, owing to the close resemblance of the two minerals but in that year Scheele showed that whereas graphite was

entirely consumed on prolonged ignition molybdenite on the other hand left a white crystalline oxide. And in 1782 Hjelm succeeded in isolating the metal itself. Molybdenite is readily distinguished from graphite by its greater specific gravity, by its greenish streak on porcelain and by its chemical properties.

Molybdenite is often found disseminated through granite, gneiss, limestone and other crystalline rocks, but frequently in greater abundance in quartz-veins traversing such rocks. In some instances where the enclosing silicious gangue has been removed or disintegrated through atmospheric or aqueous agencies or both, the molybdenite has been found loose in the soil, having apparently suffered but little alteration.

Molybdite or molybdic oxide, the earthy varieties of which are also known as molybdic ochre, contains under normal conditions 66·7 per cent of metallic molybdenum. It occurs in capillary crystallizations, tufted and radiated; also subfibrous and as an earthy powder or incrustation. The lustre of the crystals is generally silky or adamantine, less often pearly. The colour varies from straw-yellow to yellowish-white. The hardness varies from 1 to 2 and the specific gravity from 4·49 to 4·5. This mineral frequently occurs in association with molybdenite from which it has been derived by oxidation.

## Estimation of Molybdenum in its Ores.

The following methods are in common use for the estimation of molybdenum in its ores.

Estimation of molybdenum in its ores.

*Gravimetric method of H. Borntraeger*:—About one gramme of the powdered ore is digested in an Erlenmeyer flask with 25 c.c. of concentrated nitric acid for two hours in order to convert the molybdenum into molybdic acid. The latter is dissolved in ammonia and filtered off: the residue is treated a second time with nitric acid and ammonia: the combined filtrate is then acidified with nitric acid and evaporated to dryness. The molybdic acid is separated from the dry ammonium nitrate by digesting and washing with 50 per cent alcohol, which dissolves only the ammonium nitrate. The molybdic acid is then collected on a weighed filter or dissolved in normal ammonia and the excess of ammonia titrated with standard acid.

*Volumetric method.*—About one gramme of the finely powdered mineral is fused with sufficient sodium peroxide in a nickel crucible. The mass is then allowed to cool, after which the melt is dissolved in $H^2SO^4$. The solution is then neutralized with $NH^4OH$ and the pre-

cipitated ferric oxide filtered off and washed. The filtrate is now acidulated with $H^2SO^4$ and passed through a column of metallic zinc (Jones reductor) and titrated with potassium permanganate.

*Electrolytic method of L. H. Pollock and Edgar F. Smith*:—The finely divided ore is fused with $Na^2CO^3$ and $NaNO^3$; the melt after cooling is digested in water, filled and washed. The filtrate is acidified with $HC^2H^3O^2$ and the molybdenum is precipitated electrolytically as a black adherent coating of hydrated molybdenum sesquioxide, which is dissolved in $HNO^3$ and weighed as molybdic oxide.

## METALLURGY.

Metallurgy.

Pure ammonium molybdate is ignited and molybdic oxide is mixed with carbon in the proportion of ten to one and the mixture subjected for six minutes to the arc produced by a current of 800 amperes and 60 volts, care being taken to avoid complete fusion of the mass and resultant union of the molybdenum with free carbon present.

Molybdate of calcium is heated with carbon.

Molybdenite—native sulphide of molybdenum—is heated in a carbon tube with an arc of 350 amperes and 60 volts; sulphur dioxide is evolved and when the current is increased to 900 amperes and 50 volts, complete fusion is obtained in a short time and the sulphur is entirely expelled. The metal prepared in this way, contains sometimes as much as 7 per cent of carbon, about one-sixth of which is in the form of graphite. This carbon may be removed by heating with molybdic oxide.

Metallic molybdenum prepared by any of the above methods is a malleable white metal of silvery lustre and has a specific gravity of 9·01. It is sufficiently hard to scratch glass and can be welded, filed and polished with ease. It has a high melting point, but in the electrical furnace may be fused with ease. It takes up carbon by cementation. Under ordinary circumstances moist air has no effect on it. At 500° to 600°C it takes fire and burns with great brilliancy.

J. Feree (Comptes rendus de l'Académie des Sciences, Vol. CXXII, p. 733) describes the preparation of amalgams of mercury and molybdenum. The molybdenum may be separated from the mercury by distilling off the latter in vacuo at a low temperature. Thus prepared molybdenum is pyrophoric, taking fire in the air with formation of oxides which are volatilized by the heat liberated; this property is lost when the metal has been heated above 400°C. Nitrogen, carbon

dioxide and hydrogen have apparently no action on the metal either at the ordinary temperature or at a low heat. Carbon monoxide, however, is rapidly decomposed when the molybdenum is gently heated; the metal becomes red hot and absorbs the oxygen of the gas, carbon dioxide being deposited. This modification of the metal becomes incandescent in a current of sulphur dioxide, which is wholly absorbed with formation of sulphide and oxides of molybdenum. Exposed to nitrogen tetroxide, it becomes incandescent, nitride and oxides of molybdenum being formed.

## Uses.

Various uses.

Up to within very recent years the use of molybdenum was almost entirely confined to its employment in the form of a molybdate as a laboratory test-reagent for the detection of phosphoric acid. For a time small quantities of molybdenum were employed in the preparation of certain pigments used in the colouring of textile fabrics. But since the introduction of aniline compounds into the dying industry, little, if any molybdenum is now used for this purpose on a commercial scale. Recent experiments of M. E. Pozzi-Escott have demonstrated the possible use of molybdenum salts as a means of imparting a deep yellow colour to leather. Various shades may be obtained by combining these salts with logwood extracts. Lately, molybdenum has gained considerable economic importance through its introduction into the manufacture of certain kinds of steel. In quantities up to about 4 per cent, it has the effect of rendering steel peculiarly hard and tough, with the additional advantage that heating and welding are unattended by any deterioration or change in these qualities.

Different kinds of tool-steel contain from 2 to 4 per cent and a steel containing 3 per cent of molybdenum has been found eminently suitable for the manufacture of armour-plates, owing to the high degree of resistance it offers to the passage of projectiles.

For other purposes, from 1 to 2 per cent of molybdenum is employed, according to the use for which the steel is intended. At the steel-works it is ordinarily added in one or other of three different forms, viz: as dark blue powdered metal, containing 95 to 99 per cent of molybdenum; as ferromolybdenum, containing 50 to 55 per cent of molybdenum; or as molybdenum-nickel, containing 75 per cent of molybdenum and 25 per cent of nickel.

The effect which the addition of molybdenum has on certain other metals—notably lead and copper—has been the subject of attention from a number of investigators, but so far no very definite conclusions seem to have been arrived at and very little has been published in this connection as yet.

## Market Requirements.

Molybdenum ore, to be of marketable quality should contain at least 42 per cent of molybdenum. Ores containing less than this amount must be subjected to concentration by cobbing or other suitable means. It should too as far as possible be uncontaminated by other metallic minerals as the presence of any of these is objectionable and materially reduces the market value of the ore. Market requirements.

The presence of copper especially in any thing more than traces ren ders molybdenum ores valueless as such for commercial purposes, as the cost of its removal by chemical means, more than offsets the present value of the molybdenum.

## Sources of Supply.

For many years the world's supply of molybdenum ore was drawn almost exclusively from a very few localities in Norway and Sweden. Latterly however the demand has stimulated the production at other centres, notably in Saxony and in the United States of America. Many deposits of molybdenite have been developed in the states of Arizona and New Mexico and are now producing large quantities. Sources of supply.

Some localities in the states of Washington and Colorado are also being made productive and a deposit of molybdite near Telluride in the last mentioned state is being operated with success. In Canada, comparatively little has been done in the production of molybdenum ore, although it is known to occur at many localities scattered over a very large area of the Dominion. As to the extent or value of any of these deposits very little is known except from purely surface indications or from the little development work which has been carried on in one or two isolated cases.

## Canadian Occurrences.

The following list of Canadian occurrences of ores of molybdenum has been compiled from different sources but mainly from the reports of the Geological Survey of Canada. Occurrences in Canada.

*Province of Nova Scotia.*

Canadian occurrences.

*Cape Breton county*—Along the coast of this county, thick bands of laminated quartz, running with the strike of the felsites contain, in most instances, small quantities of molybdenite. It has also been observed spotting syenitic rock on the Gaspereaux river road.

*Shelbourne county*—A small vein has been noted in a brooklet tributary to the Jordan river, about six miles above Jordan falls.

*Province of New Brunswick.*

*Charlotte county*—Molybdenite has been observed on Trout brook about two miles north of the post road in the parish of Pennfield; in granitic rocks near St. Stephen; and also in quartz veins cutting the granite near Gaspereaux station in the parish of Clarendon.

*Gloucester county*—Molybdenite has been found in granitic rocks near Bathurst on the Nepisiguit river.

*York county*—Molybdenite occurs in thin foliated hexagonal plates in quartz veins traversing gneiss at the mouth of Burnt Hill brook, a tributary of the South-west Miramichi river.

*Province of Quebec.*

*Megantic county*—At Harvey Hill in the township of Leeds, a fine granular form of molybdenite has been found in some of the short veins of quartz and bitter-spar which intersect the copper-bearing slates of this locality.

*Saguenay county*—At Quetachoo river, Manicouagan bay, molybdenite has been found in nodules of from one to three inches in diameter and also in flakes a quarter of an inch thick and sometimes twelve inches across in a bed of quartz interstratified in a white coarse-grained gneiss holding garnets and black mica.

*Ottawa county.*—At the "Trusty Pit" on lot 12, range 12 of the township of Templeton, molybdenite has been found imbedded in iron-pyrites, apatite and pyroxene. And on lot 69, range 4 of the township of Egan, foliated masses of molybdenite are to be found either loose in the soil or imbedded along with lamellar aggregations of brown mica and large quantities of pyrite in a massive pyroxene. The loose condition of the masses of molybdenite in the soil has been ascribed

to the weathering and disintegration of a highly pyritiferous pyroxene. In addition to the above, small quantities of an earthly form of molybdenite occur at this locality. Canadian occurrences.

*Pontiac county.*—Molybdenite has been noted in the township of Alleyn; on lots 1 and 2, range 3 of the township of Aldfield, where some very fine crystals have been found as well as others of a lesser degree of perfection; on lot 13 of the north range of Calumet island; near Waltham at the mouth of the Black river; and at lake Kewagama to the eastward of Lake Abitibi.

*Province of Ontario.*

*Addington county.*—Molybdenite in masses said to reach as many as six inches in diameter is reported to occur in a zone carrying pyrrhotite, pyrite, hornblende, calcite, quartz, pyroxene and black mica on lot 5, concession 14 of the township of Sheffield.

*Carleton county.*—Molybdenite occurs in considerable quantities in a dyke of felspar cutting crystalline limestone on lot 6, concession 6 of the township of March.

*Frontenac county.*—Molybdenite has been found on lot 3, concession 8 of the township of Miller.

*Haliburton county.*—On lot 3, concession 1 of the township of Harcourt, a granular green pyroxenite which has been formed by the complete alteration of a mass of limestone, enclosed in the fundamental gneiss, holds small stringers of an association of molybdenite, pyrite, pyrrhotite, tourmaline and sphene.

*Hastings county.*—Molybdenite occurs on lots 26 and 27, concession 6 of the township of Monteagle.

*Leeds county.*—Molybdenite has been noted on lot 14, concession 5 of the township of North Crosby.

*Renfrew county.*—Masses of molybdenite, generally coated with pulverulent molybdite, are distributed rather abundantly through what is probably an intercalated mass of quartz enclosed in gneiss at Rose's mine on lot 22, concession 2 of the township of Ross; molybdenite also occurs in association with apatite, scapolite and titanite in a vein of limestone at Elliott's mine on lot 7, concession 9 of the same township; it also is found on lot 15, concession 10 of the township of

Canadian occurrences.

Bagot; and on lot 16, concession 1 of the township of Brougham, it occurs in large foliated masses.

*Victoria county.*—Near Mud Turtle lake, on lot 5, concession 2 of the township of Laxton, molybdenite and small quantities of molybdite with which the former is often coated, associated with pyroxene, calcite, black mica, pyrite and a few specks of pyrrhotite and hornblende occur in a quartzose veinstone which traverses the crystalline limestone of the district.

*Nipissing district.*—Molybdenite occurs as an accessory constituent of quartz-veins in the district immediately around Lake Nipissing.

*Rainy River district.*—Molybdenite has been noted in small veinlets traversing granitoid gneiss, on Quarry island, Lake of the Woods; and flakes of it are common in a quartz vein at the contact of the Huronian and Laurentian series at the Bear's passage, Rainy lake.

*Thunder Bay district.*—Molybdenite has been observed near River Dore near Gros Cap above Michipicoten on Lake Superior; also at Black river, and in quartz veins at Terrace cove.

### *District of Ungava.*

*Great Whale river.*—Molybdenite has been reported from near the mouth of this river.

On Island No. 12 of the Paint Hills group off the east coast of James bay, foliated masses and crystalline plates of molybdenite with a more or less perfect hexagonal outline are found imbedded in a reddish feldspar and a grayish-white subtranslucent quartz, constituents of a pegmatite vein cutting trap at this locality.

### *District of Keewatin.*

*Cross lake.*—Molybdenite has been found in a pegmatite dyke cutting granite near this lake.

### *District of Saskatchewan.*

*Nelson river.*—Rounded crystalline aggregates of molybdenite along with occasional crystals of pyrite and magnetite are to be found in

veins of red pegmatite cutting granitite on the Nelson river a short distance from where it leaves Playgreen lake. Canadian occurrences.

*Province of British Columbia.*

*East Kootenay district.*—Fine flakes of molybdenite have been found in a quartz vein traversing altered granite near Granite Crossing on the Kootenay river.

*West Kootenay district.*—Molybdenite has been found at some of the mines in the Trail Creek region. That of the Deer Park mine has been reported to be auriferous. At the Giant claim it is found in bright bluish-gray fine granular masses, sometimes exceeding a foot in diameter, associated with galena, pyrrhotite, chalcopyrite and arsenopyrite.

*Yale district.*—At a point about three miles south-west of Grande Prairie, fine specimens of molybdenite have been found accompanying chalcopyrite in a gangue composed of a massive clove-brown andradite associated with a light greenish fine-grained pyroxene. Fine specimens of molybdenite have also been found near the headwaters of the south fork of Spuzzum creek.

*Lillooet district.*—Molybdenite has been observed in the neighbourhood of Lillooet river.

*Westminster district.*—Molybdenite has been found in association with copper ore near the head of Salmon arm, Jarvis inlet.

*Comox district.*—Molybdenite has been noticed in the neighbourhood of Knight inlet.

*Cowichan district.*—(Vancouver island)—.Molybdenite has been reported from the upper part of Cowichan river.

*Cortez island, Strait of Georgia.*—Small quantities of molybdenite have been found in quartz veins in an obscurely stratified hornblendic granitic rock at a point just east of Carrington bay.

*Texada island, Strait of Georgia.*—Molybdenite has been observed at the Malaspina copper mine, associated with copper- and iron-pyrites in a vein consisting of calcite and quartz, with andradite, tremolite and chlorite as accessory minerals.

*Yukon Territory.*

*White Horse copper region.*—Molybdenite is known to occur in some of the prospects in this region.

## TUNGSTEN.

Tungsten.

Owing to the similarity of the applications of molybdenum and tungsten in the arts, it has been thought not inadvisable to add here a few notes regarding the latter metal, and to collect together in convenient form, such information as is available, regarding its occurrence in Canada.

The addition of tungsten to steel produces properties almost identical with those produced by the addition of molybdenum. For this purpose, though, it is necessary to add the tungsten in very much greater amount than is the case with molybdenum; 9 per cent of the former produces about the same effect on steel which is obtained with 4 per cent of the latter. It is in this connection that tungsten is for the most part used. Recent experiments have also shown that the addition of tungsten has a very beneficial effect on certain of the aluminum alloys, particularly those with copper. Small quantities of it are also consumed in colouring textile fabrics, and tungstate of soda is used for rendering such materials fireproof.

Ores of.

The most important ores of this metal are scheelite or tungstate of calcium; wolframite, which consists essentially of tungstate of iron; and hubnerite, which consists essentially of tungstate of manganese; there are however many intermediate varieties between the last two types, the iron and the maganese replacing each other in varying amounts.

These ores form frequent accompaniments to tin ores and in some instances have been profitably worked in connection with the gold-washings of placer-mining.

The chief countries producing tungsten ores are England, Austria-Hungary, Germany, Australia and the United States of America.

### Canadian Occurrences.

As in the case of the ores of molybdenum mentioned in a preceding list the following enumeration of Canadian occurrences of ores of

tungsten has been compiled almost wholly from the reports of the Geological Survey of Canada.

*Province of Nova Scotia.*

*Inverness county*—A deposit of wolframite is mentioned in 'The Mineral Industry' for 1900 as occurring at north-east Margaree and the following analysis is given of the ore : $WO_3$ 66·32%; $SiO_2$ 6·25%; MnO, 12·02%; FeO, 12%. And in the Annual Report of the Geological Survey of Canada, Vol. II, 1898, p. 10 R., is described an occurrence of hubnerite at Emerald on Tom Murphy's brook. This stream empties into Big brook about midway between Pine and Coady brooks which are likewise tributary to Big brook. The mineral was here found associated with small quantities of chalcopyrite and a very little pale yellow hydrous mica, irregularly distributed through a mass of light grayish-white translucent quartz, weighing about a ton and a half, found lying at the outcrop of a lenticular vein of similar quartz some two feet and a half to three feet in width, cutting a gneissic or granitic rock of Pre-Cambrian age. The vein however contained but a comparatively small scattering of the mineral and that only for about a couple of feet. It here occurs in the quartz in the form of narrow seams and small irregular masses having a coarsely laminated structure; it has a brownish-black colour, a submetallic lustre, breaks with a small subconchoidal fracture and affords a brownish-yellow streak. It was found to have a specific gravity at 15·5°C of 6.975 and analysis showed it to have the following composition: $WO_3$ 74·28%; $MoO_3$ trace; MnO, 22·73%; FeO, 0·47%; CaO, 0·02%; MgO, 0·86%; $SiO_2$, 1·33%. Wolframite in Inverness county.

*Queens county*—Scheelite is found associated with a little arsenopyrite and pyrite, in a quartz-lead intersecting the main auriferous vein at the Ballou or Old American mine, Molega gold mining district. It possesses a compact massive structure and shows an uneven fracture; it is light smoke-brown in colour and has a vitreous lustre; it is subtranslucent; has a specific gravity at 15·5°C. of 6.002; and on analysis, yielded the following composition: $WO_3$, 79·01%; CaO, 19·80%; $CO_2$, 0·71%; insoluble matter, 0·11%. Deducting the $CO_2$ together with its equivalent in CaO, to form $CaCO_3$ and also the insoluble matter, and recalculating the remaining constituents for one hundred parts, the following figures are obtained as representing the composition of the mineral; $WO_3$, 80·70%; CaO, 19·30%. Scheelite Queens county.

*Province of Quebec.*

*Beauce county.*—On lot 1 of the 7th range of the township of Marlowe, scheelite occurs in crystals of a pale wine-yellow colour associated with specular iron, pyrrhotite, galena and copper—and iron-pyrites in quartz veins cutting the Cambrian slates of the district. At this locality the scheelite is sometimes accompanied by small quantities of tungstite and meymacite. The mineral has a specific gravity at 15·5° of 6.059 and its analysis showed it to have the following composition : $WO_3$, 79·90 per cent ; Ca O, 19·37 per cent, $Fe_2 O_3$, 0·70 per cent ; $Si O_2$, 0.29 per cent.

*Province of Ontario.*

*Simcoe county.*—On the north shore of Chiefs island, Lake Coutchiching, Professor E. J. Chapman once found a boulder of Laurentian gneiss in which he observed crystals of wolframite associated with magnetite. These crystals, he found to have a specific gravity of 6.938 and the following composition : $WO^3$, 73·45 per cent ; a substance having the characters of niobic acid, 1·95 per cent ; Fe O, 9·05 per cent ; Mn O, by difference, 15·35 per cent ; $SiO^2$, 0·20 per cent.

## NOTES ON MOLYBDENITE.

By Mr. C. W. Willimott of the Geological Survey.

As the demand for molybdenite has increased very much within the last year or two, more attention is being paid to the search for this mineral, and reports of new finds are reaching us from all parts of Canada. In Ottawa and Pontiac counties, its occurrence may be said to extend, at intervals, over a length of one hundred and fifty miles. At Eardley in Ottawa country it has been found on lot 2, range VIII. In the township of Hull, it is first met with at Eaton chute, near Kirks Ferry, where it occurs sparingly in felspar in small scales. A few yards east of this place, on the bank of the Gatineau river, I observed a number of loose pieces of quartz holding molybdenite in foliated masses. On the west side of the river, on a property belonging to Mr. Featherstonhaugh, a large mass of this mineral was thrown out of one of the pits, while excavating for mica. The next place where I observed this mineral was on lot 6, range I, in the township of Wakefield, but in very small quantity.

On the east side of the Gatineau in the township of Masham, molybdenite has been met with at a number of places. Four miles west of the village of North Wakefield, on the farm of Mr. R. Daly, this mineral occurs in veins and was tested by Mr. Henry, of the Molybdenum Company of Cooper, Maine, U.S., who stated that it ran three and three fifths per cent of molybdenite. At another place in the same township, I observed beautiful hexagonal crystals, about an inch in diameter, on the face of a protruding rock.

In Oldfield, the next township in Pontiac county, on lots 1 and 2 in the third range, a band of grayish pyroxene has been penetrated in several places to a depth of fourteen feet. At the surface, in one of these openings, some very fine crystals of molybdenite were found several years ago by Mr. Chapman, of Belleville, more recently an attempt was made to work this locality, but without satisfactory results. The mineral became very scarce at the depth of a few feet. Among the debris of the pits which had been sunk, I noticed two zeolites, chabazite and stilbite, associated with scapolite.

In the township of Alleyn, in the same county, on lot 1, range II, molybdenite, in small scales, is distributed throughout the country rock. The latter is intersected by felspathic veins that sometimes hold a considerable quantity of molybdenite. On lot 10, range II, of the same

township, this mineral is often turned up by the plough. From this locality to a point forty miles north of Maniwaki, it would be safe to say that molybdenite is found at frequent intervals over a wide range of country. I have seen specimens, said to have come from the townships of Alwin, Wright and Bouchette.

At Mount Cerf on lot 69, range IV, Egan, there is a band of ferruginous pyroxene which is, for the most part, covered with a peaty soil. At one small outcropping on this band, molybdenite makes a considerable showing, and foliated masses and plated crystals of the mineral, sometimes weighing five pounds, were met with. From two shots, I obtained thirty-nine pounds of the pure mineral. I sent two hundred and fifty pounds of the enclosing rock to the Museum, which was later examined by Prof. Porter, of McGill University, who found it still to contain 2·8 per cent, making a total percentage of 15·92. (See Summary Report of the Geological Survey Department for 1900, page 10.)

Molybdenite was also found in loose pieces in the soil about twenty yards off at right angles to the strike. I was shown some very fine specimens of this mineral by an Indian, who stated that they came from the Tomasine river, but I had not an opportunity of visiting the locality.

In the township of Litchfield, on lot 21, range XI, a number of pits have been made in prospecting for mica. During the progress of this research a noticeable quantity of molybdenite was met with in all the pits. From one small pile, I picked out a piece that measured five by four inches and was a quarter of an inch thick. I was informed by the owner of the property that he had seen pieces as large as a dinne plate. This property has been recently well exploited with a view to finding a place that might afford some encouragement to start mining the molybdenite, but so far, I believe, no such spot has been found. From one little pocket I extracted about two pounds of the mineral.

NATURAL SCIENCE
TN
226
A3
903
1.10

877

GEOLOGICAL SURVEY OF CANADA
ROBERT BELL, M.D., D.Sc. (CANTAB.), LL.D., F.R.S., I.S.O.

# MINERAL RESOURCES OF CANADA

## BULLETIN

ON

# GRAPHITE

BY

R. W. ELLS, LL.D., F.R.S.C.

OTTAWA
PRINTED BY S. E. DAWSON, PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1904

No. 877

THE UNIVERSITY OF

Natural Science
Library
TN
226
.A3
1903
V.10

# GRAPHITE IN CANADA

By R. W. Ells.

Graphite or plumbago, as a mineral, is widely distributed both in Canada and the United States. It is found in rocks of widely different geological horizons in both countries, but, generally speaking, the largest and most valuable deposits from the economic standpoint, appear in all cases to belong to the older crystallines of pre-Cambrian age, which are referable to what has been usually regarded as the Laurentian system.

Mode of occurrence in Canada and the United States similar.

In Canada, the largest deposits yet known clearly belong to the gneiss and crystalline limestones which mark the upper portion of the Grenville series, with which are associated numerous dykes or masses of eruptive rocks of various kinds. In the State of New York also, as at Ticonderoga, where the largest deposits at present worked in the United States are located, the mineral occurs in rocks similar to those in which it is found in Canada, the New York rocks being the extension southward of those which are so largely developed north of the Ottawa.

The celebrated deposits which have been mined for so many years in Ceylon, and the output from which forms the largest portion of the imports of this mineral into the United States, are apparently derived from crystalline rocks similar to those found in Canada. The mineral there occurs largely as the foliated and columnar varieties and is of great purity, and while the geological horizon of the containing rocks is not definitely stated they appear to represent some portion of the Archæan.

Ceylon deposits.

The mineral graphite is composed largely of carbon with a certain variable percentage of iron. At a high temperature it burns without flame or smoke and leaves a red ash which is practically a red oxide of iron. It occurs principally in gneiss, mica-schist, crystalline limestone and in granite and diorite intrusions. Among the sedimentary series it also occurs with coal, forming a graphitic anthracite, in which form it is mined to some extent in Rhode island. Similar graphitic

carbon is found in the coal basin of Massachusetts, and also in connection with a deposit of graphitic anthracite in southern New Brunswick. It is also associated with beds of somewhat altered clay shales and slates of more recent date than the crystalline rocks in a number of places.

Several varieties.

It is found in several forms, including the disseminated variety where it occurs as scattered scales or plates through certain portions of the gneiss, limestone or other sedimentary strata; and as veins of the columnar or foliated variety which sometimes intersect granite or other intrusive rocks at all angles.

The origin of the graphite has been a subject of controversy for many years. For a long time it was generally regarded as purely organic in character, and that its presence in the disseminated form was due entirely to the alteration of organic matter which formerly entered into the original composition of such strata where found. While this statement is probably true as regards much of the flake or disseminated graphite, there are certain occurrences of the mineral in this form which yet appear open to discussion. In regard to the vein graphite, its presence in granite, diorite or other intrusive rocks in the form of true veins, appears to be decidedly against this origin, and by many it is regarded as due to the action of certain vapours strongly charged with carbonic acid which have issued along with the eruptive rocks, and which have deposited the graphitic carbon in vein form after the manner of many of the other economic minerals.

Disseminated graphite.

The disseminated graphite often occurs in proximity to the veins, and in these cases it is supposed that the disseminated graphite has thence been distributed along the planes of the rock in contact from the vein matter itself. This is more especially the case where the rock in contact is a mica gneiss, but similar occurrences are found sometimes in the limestone also. In nearly all the localities where graphite has been mined its association with eruptive rocks is clearly seen, since, when not found in the eruptive rock itself, its presence in the stratified gneiss or limestone is generally in close proximity to the intrusions, and in many cases it has been noted that the richest portions of the disseminated mineral are those nearest the granite or other intrusive rock, indicating that these intrusions have exercised a beneficial action as regards the occurrence of the graphite in the adjacent sedimentary crystalline. This feature is well seen at the mine of the North American Graphite Company and at the other mines in this district, and will be referred to more particularly in the discussion of the rocks of this part of the province of Quebec.

In considering the distribution of the graphite-bearing rocks of Canada, those which are found in the eastern portion of the Dominion will be first taken up.

## Graphite in Nova Scotia.

Graphite in Nova Scotia.

While the occurrence of graphite in certain rock-formations in Nova Scotia has been known for many years, up to the present time but little has been done in the way of economic production. Several attempts have however been made, more especially in the eastern portion of the province, to exploit deposits of this mineral, but so far these do not appear to have been attended with much success.

The principal occurrences of graphite in the province are described as belonging to the island of Cape Breton. Here the mineral is found chiefly in rocks which have been assigned to the pre-Cambrian age, consisting of crystalline limestones with slates and shales which are associated granitic intrusions. In places, as at Glenvale, River Inhabitants, Inverness county, it is found in a coarse red syenite full of graphite specks. At Dallas brook the rocks are felsites, limestones and slates with which the syenites are associated, and the limestones are graphitic, while beds of graphitic shale also occur. These black shaly beds were at one time mistaken for coal strata. The graphitic limestone is sometimes burned for lime; the horizon of these rocks is that known as the George River limestones, a portion of the Archæan.

Analysis graphitic shale.

One of the graphitic shale localities is found half a mile south of Guthro lake near the French Vale road. The band at this place is said to have a breadth of two to three feet, and can be traced for some distance on the strike. An analysis of this shale was made in the laboratory of the Geological Survey and gave graphite 38·387 per cent. Report of Progress Geol. Surv. Can., 1879-80 p. 1-2. The purified graphite from this place, when completely separated is of fair quality, and appears to be well adapted for lead pencils, electrotyping, and for most of the numerous uses for which graphite is available. Its value as an economic product would appear therefore, to depend largely upon the cost of its extraction and preparation for the market, necessary to ensure the requisite amount of purity.

The percentage of graphite in the Glendale shales appears to vary considerably in different parts. Thus, samples, collected in 1878 by Mr. Hugh Fletcher and assayed in the Geological Survey laboratory, gave of graphite only 13·965 per cent, but a more recent assay by Dr. Hoffmann, of

material from the same deposit, made for Mr. James McIntosh, yielded graphite 31·8 per cent. A later assay is given in the Report of the Mines Department for Nova Scotia, of the shales from Christmas island which is practically the same deposit, in which the percentage of graphite is given as 50·23, with rock matter 43·37 and water 6·50. These shales apparently belong to the Cambrian rocks of Cape Breton.

On Cameron and Dundas brooks the gneiss, hornblende schists and dark slates of pre-Cambrian age are blackened with the contained graphite, but no definite information as to the actual graphite contents are available.

Occurrences in Guysborough county.

In the county of Guysborough, near the Tor Bay road, several pits have been opened along the Salmon river in a black slate which is probably of Devonian age, and near the contact of the gold-bearing slates. These slates apparently contain a fair percentage of graphite.

The occurrence of graphite has also been reported from West bay, Grand Narrows, East bay and Hunters island, and in addition, Mr. Gilpin, in his Report of the Mines of Nova Scotia, 1880, mentions its presence, mostly in the form of plumbaginous shales, at Parrsborough, Salmon river, Musquodoboit, Hammonds plains, Fifteen-mile stream Boularderie island, Gregwa brook, and Gillis brook, the last three being in Cape Breton. Concerning the extent of these deposits, no particulars are available, and but little attempt at mining has been done for some years; so that the actual economic value has apparently never been ascertained. The above mentioned localities appear to include the principal deposits as yet known to exist in this province.

## Graphite in New Brunswick.

Graphite in Charlotte county, N.B.

The presence of graphite in this province was early recognized, and in the first Report on the Geology of New Brunswick by Dr. Gesner, 1839, its occurrence in Charlotte county is mentioned. He there describes a deposit as occurring at a point about four miles and a half north of St. Stephen on land belonging to Mr. William Porter, where he says "there is a stratum of graphite (plumbago) or black lead situated between perpendicular strata of schistose rock. This stratum had been opened and was supposed to be coal."

Since that early date several attempts to work this property as a mine have been made. It lies a short distance to the west of the Basswood ridge road, and appears to be in a slaty schist which is broken by intrusions of gabbro and granite. No mining has been done on this area for some years.

Other occurrences have been reported also from this county. Thus in the Report of the Geological Survey for 1876-77, Dr. G. F. Matthew describes certain graphitic slates at Dumbarton station on the Canadian Pacific Railway, which are associated with hard sandstones, possibly of upper Silurian age. Similar graphitic bands are found in the southern part of the township of St. Stephen, as also in the northern part of St. Patrick, but in so far as examined at the surface, the Dumbarton beds seem to be the most highly charged with graphite, and some portions of these appear to be sufficiently rich to warrant closer investigation.

Graphitic anthracite.

Near the coast of the Bay of Fundy, on the shores of Belas basin, Lepreau Harbour, there is a deposit of graphitic anthracite which was mined for coal about twenty-five years ago. Several shafts were sunk, one of which reached a depth of 140 feet. The thickness of the band of black shale and coal was reported by the miners to be in places twenty feet, but this amount varies greatly along the outcrop. The amount of graphitic anthracite at the principal working shaft was said to be four feet in thickness. The deposit was highly inclined, the dip ranging from 80 to 90 degrees. The associated rocks are of Devonian age. While strongly graphitic the coal burned readily under a good draught until the carbonaceous matter was consumed, but left a large amount of reddish ash, reaching on analysis a percentage of 36·88. (Report of Progress, Geol. Surv., Can., 1878-79, p. 13D.)

In character of coal and associated rocks this deposit closely resembles similar deposits which occur in the states of Massachusetts and of Rhode island, which were described in a report by Dr. Edward Hitchcock in 1841. This coal has been mined there from time to time but its value as a fuel is not great. It has been used for some years as a source of supply for graphite and when crushed and properly separated it furnishes a mineral of considerable value. No attempt has ever been made to utilize the Charlotte county deposits in this way, but a careful examination of the material, as to its graphite contents would be desirable.

Deposits near city of St. John.

The principal deposits, from an economic standpoint, in this province are situated near the city of St. John on the St. John river near the Suspension Bridge which connects the city with the town of Fairville. The rocks at this place are for the most part crystalline limestones with slaty schists, which have been described as of pre-Cambrian and possibly of Laurentian age. They appear to correspond closely with the limestones of the Grenville series north of the Ottawa.

The presence of graphite at this place was mentioned by Gesner in his report for 1840, in which he says "the limestone of the hill contains several veins of graphite or plumbago, one of which is on the north side of the main street, and is upward of four feet in thickness. This graphite is too impure for the manufacture of lead-pencils. It is occasionally used for varnishing stoves and lessening friction, and may at some future period afford an article of limited export."

Mined for many years at intervals.

Mining has been carried on at intervals at this place for many years. In 1853, Mr. M. H. Perley reports that as much as 89,936 lbs. were exported, but the mine evidently closed down shortly after this date. It was reopened in November, 1868, by Mr. Garrett, and the returns of the output for 1869, taken from the statistics in the Geological Survey report for 1871-72, are 6,000 bbls., valued at $12,000. No further returns were received from this property and mining seems to have been suspended for a time at least.

From Professor Bailey's report on the Mineral Resources of New Brunswick, 1897, it would appear that mining operations were again resumed for a short time. A little later, probably about 1872, work was again commenced on this property, by Mr. S. S. Mayer, of Carleton, at a point about 600 yards east of the river, on the land of Messrs. Hazen and Botsford, but after the extraction of a few tons the location was sold to parties in the United States. The works were closed down shortly after, but later another attempt was made by Mr. W. F. Best and others to revive the industry, at a point about 200 feet east of the Mayer location. At this place the graphite was concealed at the surface, but on sinking a shaft, it was struck in small quantity or showing at a depth of about fifteen feet. This area was regarded as a continuation of the deposit seen on the Mayer place, and the graphite is reported by Mr. Brumell, at that time on the Geological Survey staff, who examined the district in 1890, as occurring at the contact of crystalline limestone with a trap dyke. Where first struck, at eight feet from the surface, the ore-body had a thickness of only about two inches, but this rapidly increased and in the shaft it reached a volume of eight to ten feet at a depth of 50 feet. A mass of trap with a thickness of two feet, which extended for 50 feet along the deposit, was struck at a depth of 30 feet from the surface. The dip of the hanging wall is to the south at an angle of 55 degrees. The graphite is associated in places with pyrite which breaks away readily and leaves the graphite comparatively pure. The output is said to have found a ready market at $7 per ton. Its occurrence is also recorded in the graphitic shales which are regarded as a part of the crystalline

Later attempts at mining.

limestone series. 'See Annual Report Geol. Surv. Can., 1890-91, page 71 ss.'

All these openings near the St. John river appear to be practically on the same deposit or on deposits of similar character. In connection with the ore from what is known as the Split Rock mine, samples were obtained by Mr. Wallace Broad in 1877 for the Geological Survey, which were examined by Dr. Hoffmann. The material had a loose slaty structure, parting into somewhat irregular and lenticular fragments, with a greayish black colour, submetallic lustre and a black streak. A certain amount of pyrite was found in the specimens, and after separating the earthy portions with the pyrite the analysis of the ore gave of graphitic carbon, 48·775, rock matter 50·058, and hygroscopic water 1·167 per cent.

Result of tests made in England.

Samples of the prepared carbon were sent to persons in England for a practical test of values, and as a result it is stated that, "in the one case the examination has shown the graphite to be of fair quality and adapted to the manufacture of the commoner kinds of lead-pencils; although its 'quality and nature' do not equal, as far as suitability for pencil-making is concerned, the graphite obtainable in Bohemia and some other places." "In the other case, and as regards its employment in electrotyping, the trial did not give a very good result; it was not considered so good as that which they were in the habit of using for that purpose." (Report of Progress, Geol. Surv. Can. 1878-79, pp. 3-4 H.)

Dr. Hoffmann further remarks on the mineral which was sent, that it was in the most favourable condition, containing only 0·16 per cent of a light coloured ash and therefore, as far as purity was concerned, left nothing to be desired. The failure to meet the higher requirements of the application of graphite, notwithstanding its purity, was thought by him to result from its state of physical aggregation, as implied in the terms "quality and nature" quoted above

While the mineral at this locality is found in connection with the crystalline limestones at several points, the portion best adapted for mining appears to belong rather to certain bands of argillite or slaty schist through which the ore is disseminated. These bands vary from one to four feet in thickness. The graphite obtained from these places has been used quite extensively for foundry facings for which purpose it is well adapted, and in the manufacture of paint, but for the higher grades its value on the commercial scale has apparently never been demonstrated.

Importance of preparation for market.

For some years the ore was shipped in the rough after hand picking, but later a mill was erected and the graphite was for a time cleaned and prepared for the market on the spot. Unfortunately details of the milling plant are not available, and its fitness for the work can not therefore be judged; but as the proper milling and grading of the graphite is a very important feature as regards the market demand, it is possible that some of the failures which have attended this industry in the past may be due to a lack of the best methods for cleaning and separating the final product. That there is a large amount of the ore in this district has been quite clearly established, and in so far as the returns show there does not appear to be any marked reason why, with more suitable methods of mining and treatment, profitable returns should not be received from the capital invested.

Graphitic shales have been reported as occurring at various other points in the province. Thus Prof. H. Y. Hind, in his report on the geology of the province, 1865, mentions its presence at several places, including Portland, just described, Hammond river, the locality four miles north of St. Stephen, already alluded to, Dorchester, Mackerel cove, one mile east of Goose river on the shore of the Bay of Fundy, and at Goose creek itself. Most of these are in slaty bands of different geologic horizons, and appear to be of small, if any, economic importance.

Graphite in Kings county.

In the extreme north-eastern corner of Kings county, on what is known as Thorns brook, there is a belt of dark graphitic shale or slate on the property owned by Charles McAlpine. The beds strike north-east, and for a breadth of some twenty feet show the presence of an earthy graphite which can be traced on the course of the outcrop for nearly a mile. The graphite is nowhere in the solid form and the slates are jointed and broken, being readily removed with pick and shovel. This property was opened up to some extent and a company was formed to carry on mining operations. The percentage of graphite, however, appears to be too low to warrant the investment of much capital in its development.

## GRAPHITE IN THE PROVINCE OF QUEBEC.

The occurrence of graphite in the province of Quebec was noted by Sir W. E. Logan in the Geological Survey Report for 1846, at several places in the townships of Grenville and Chatham Gore. Mining, probably the first of the kind in Canada, was commenced on the Grenville deposits about that time or a little earlier, by the Hon. Mr. Harwood, of Vaudreuil, on a mineral-bearing vein which cut the

crystalline limestone of the Grenville series. In the early reports of the survey, considerable attention was given to the subject of graphite by Dr. T. S. Hunt, and a large amount of interesting and valuable information, relating to modes of occurrence, treatment of ores and uses was published.

Mode of occurrence in the Eastern Townships.

In the Geology of Canada, 1863, page 529, it is stated that 'plumbago occurs in the altered rocks of the base of the Palæzoic series, in the Eastern townships, generally finely disseminated in calcareous or argillaceous shales, rendering them soft, unctuous, black and shining; but it has nowhere been found among them in sufficient quantity to be of economic value. Examples of these plumbaginous slates are to be seen, among other localities, in Granby, Melbourne, and St. Henry; in the latter place enclosing graptolites. The altered Devonian limestones of Owls Head (Memphremagog lake) are also plumbaginous. The plumbago which is found in Massachusetts, in the continuation of this metamorphic region, is well known to belong to more recent rocks, and to be, in fact, the coal of the Carboniferous system in an altered condition. The principal deposits of plumbago in Canada, however, belong to the Laurentian series, and by analogy suggest the existence of great accumulations of organic matter in the sediments of that remote period.'

Mode of occurrence in Laurentian rocks.

'The plumbago of the Laurentian rocks generally occurs in beds or seams of from a few inches to two or three feet in thickness. These are often interrupted, giving rise to lenticular masses, which are sometimes nearly pure, and at other times mingled with carbonate of lime, pyroxene and other foreign minerals. These deposits of plumbago generally occur in the limestones or in their immediate vicinity, and granular varieties of this rock often contain large crystalline plates of plumbago. At other times this mineral is so finely disseminated as to give a bluish-gray colour to the limestone, and the distribution of bands thus coloured serves to mark the stratification of the rock. Workable deposits of plumbago occur in the townships of Burgess, Lochaber, and Grenville. In one locality in the latter township, it is associated with sphene, zircon, pyroxene and tabular-spar,' (Wollastonite).

'The plumbago of the Laurentian series is, however, not confined to the limestones. Large crystalline scales of it are occasionally disseminated in pyroxene rock, in pyrallolite, and sometimes in quartzite and in felspathic rocks, or even in magnetic oxyd of iron, as at the Hull ore-bed.'

Result of recent investigations.

The description of the mode of occurrence given above, is on the whole applicable to the deposits as known at the present day. The investigations of recent years have, however, brought to light certain points in this regard which will be described. It may be now stated that the valuable deposits of the mineral in this province are practically confined to the crystalline limestones and associated grayish and mica-gneiss which form the upper members of the Grenville series, formerly regarded as representing the middle or upper part of the Laurentian system.

In these rocks, which are cut by frequent masses of intrusives, including granite, diabase, pyroxene, &c., graphite occurs at many widely separated points. The occurrences noted as found in the slates of the Eastern Township have never been deemed of sufficient importance to warrant development in view of the great deposits seen in the crystalline rocks north of the Ottawa. Of these, the most important are found in the townships of Buckingham and Lochaber in the county of Ottawa, and in the township of Grenville, Argenteuil county. In this part of the province all the workable occurrences are at present located and some of them have been operated at intervals for many years. The graphite at these occurs both in the form of disseminated flakes, usually in the gneiss and limestone, and as true veins, both columnar and foliated, which are also found frequently cutting the granite and other igneous rocks, as well as the gneiss.

Mineral widely distributed.

A carefully prepared list of localities has been made showing the areas in which graphite has been found, and in some of which mining has been carried on with more or less success at intervals. From this list the wide distribution of the mineral will be readily seen.

Among the first localities where mining operations on graphite were conducted are those in the township of Grenville. Several occurrences of the mineral are known in this district, among the principal of which may be mentioned the following:

Lot 10, range V, the first recorded, afterward known as the Miller mine, worked at intervals by various companies for about 60 years; and recently by the Keystone Graphite Co. of Wilkesbarre, Pa.; lot 9, same range, adjacent on the east, opened in 1900 by the National Graphite Co. of Scranton, Pa.; The Calumet Graphite Co. on ranges II and III in rear of Calumet station on the Canadian Pacific railway, worked in 1899, 1900; and lot 2, range X.

In the Augmentation of Grenville, on lot 1, range VI; lot 3, range II; lots 13-14, range IV; lot 3 range VI; lot 8, range IV.

In Chatham Gore, lot 5, range IV.

Other localities doubtless will be found for the mineral in connection with the crystalline limestones where these are developed, but the above, apparently represent the principal deposits at present known to exist.

Extensive deposits in Lochaber and Buckingham townships.

In the townships of Lochaber and Buckingham, graphite deposits have a very extensive development. The reason for this is not entirely clear, unless it may be due to some extent to the numerous areas and dyke masses of intrusive rocks, such as granite, pyroxenite, diabase, &c., which traverse the crystalline limestone and associated gneiss in all directions, and which have, as in the case of the micas and apatite, exercised a marked influence on the occurrence of the graphite at certain points.

In Lochaber township, deposits, some of which are of considerable extent, and have been mined at intervals for forty years, are found on lot 24, range VII; lot 10, same range; lot 23, range XII; lots 23, 24, 25, range VIII; lots 22, 23, 26 and 28, range X; lots 21, 23, 24, 25, 26, 27, range XI.

In the township of Buckingham, which adjoins Lochaber on the west, graphite is found on lots 22, 24 range IV; lots 19, 20, 21, 22, 23, 24, 26, 27, range V; lots 15, 16, 22, 23, 24, 25, 26, 27, 28, range VI; lots 4, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, range VII; lots 19, 20, 21, range VIII; lots 4, 5, 17, 19, 21, range IX; lots 3, 4, 12, 13, 14, 17, range X; lots 4, 5, range XI; lots 23, 24, range XII.

List of occurrences in province of Quebec.

Among other widely separated areas in the province may be mentioned the following:—lots 25, 26, range, Litchfield; lot 47, XIV, Wright, lot 7, range I, Wakefield; lot 11, range II, Lathbury; lot 9, range XI, Hull; lots 1, 2, range III, Wentworth; Petite Nation, exact locality not mentioned; ranges IV, V, VI, St. Boniface de Shawinegan; on the St. Maurice river at Pointe à la Mine, two miles above the Piles; range II, S. E. Provost; Parish Ste. Ursule, range Fontarabia, Maskinongé county; lot 11, range III, Portland west; lots 23, 24, range VI, Cawood and at Babiche rapid, in the Lièvre river about 30 miles above High falls. Several of these are reported occurrences only, and on the greater number of them but little exploratory work appears to have been done.

The above list of localities for the province of Quebec has been taken largely from the publications of the Geological Survey, supplemented in some cases by the lists contained in the reports by Mr. J. Obalski, Government Mining Engineer for the province. It includes practi-

cally all the deposits at present known to the Department, but as exploration and settlement progress, other occurrences will doubtless be found in either the crystalline limestones or gneisses which have a wide development throughout the country north of the Ottawa river. In many of these areas the amount of graphite will probably be found to be too small to be of much practical importance, but of others their value as a source of supply of this mineral has long been established. The failure of profitable returns from these mines when worked, as they have been in a desultory manner, is in many cases due, probably to imperfect appliances for the proper treatment of the ore, or to bad management or too great extravagance in the part of the companies engaged in the work of mining and manufacture. The history of some of these mining developments would doubtless form interesting matter for discussion, and if available would serve to point out the difficulties to be avoided in future operations, and what improvements might be made for the more successful exploitation of some of these valuable properties.

Mode of occurrence and associations similar.

The occurrence and associations of the mineral are to a large extent the same at most of the places indicated. Certain local conditions are found here and there which must be considered in any mining scheme proposed, but generally it may be said that the chief attention as regards future developments must be made in connection with large bodies of the disseminated flake graphite, as promising the most steadfast returns. Though the vein form frequently occurs at most of the points where attempts to work the graphite have been made, and has shown in such cases a mineral of great purity, the uncertainty of such deposits is such that, by itself, the employment of capital on a large scale would scarcely be warranted.

Study of deposits made by Prof. Osann.

In 1899 a careful study of the principal deposits in Quebec was made by Prof. A. Osann of Germany, in which he examined the Grenville and Buckingham areas. His report contains many points of interest as to the occurrence and origin of the mineral, some of which, condensed, may here be presented. (Vol. XII., 1899., pp. 73-78.)

History of Grenville deposit.

The history of the Grenville deposit on lot 10, range V., may be briefly stated. First described by Logan in 1845-46, and mined for a few years, the property was abandoned for more than a quarter of a century, when it was again worked for a short time as the Miller mine. It was acquired in 1898 by the Keystone Graphite Co. of Wilkesbarre, Pa., and a considerable amount of development work was done, apparently without fully understanding the actual conditions of the deposit. This work has also been suspended for several years.

Work was also begun on lot No. 9, adjacent on the east in 1899, by the National Graphite Co. of Scranton, Pa., the rocks on both lots being practically similar in character. This work has also been discontinued.

The area was examined by the writer in 1899 and the following notes as to the occurrence of the mineral were taken.

Mode of occurrence.

The country rock is for the most part crystalline limestone which is cut by granites and other intrusives. The graphite usually occurs irregularly at, or near, the contact of the limestone with granite or diabase dykes, both rocks being present in the openings, also in irregular vein form which are massive rather than columnar in character, ranging in thickness from fifteen inches to two feet. These are not solid but apparently sometimes in dyke matter.

Several openings have been made on the property. In the main pit the rocks are limestone with bands of rusty gneiss which are traversed by a white granite dyke and this in turn by a dyke of light green diabase. The graphite occurs principally in two irregular veins, and also in the granite mass, and there is a small vein on the edge of the diabase. The veins are shattered and mixed with the whitish, sometimes reddish granite.

Other minerals included.

This granitic-looking rock has somewhat the aspect of a vein in some respects rather than a true dyke. It carries several minerals, including scapolite, hornblende, graphite, pyroxene, pyrite, apatite and others. South of the principal opening where mining has been carried on, the surface rocks for some distance appear to be all limestone, and in several small prospecting pits, sunk in this rock, a small percentage of disseminated flake graphite was observed.

Briefly summarizing the remarks of Prof. Osann on this area, it may be stated that, the mineral here occurs filling fissures as veins in the granular limestone, and is therefore younger than the containing rock. In some of the veins the graphite is the only mineral present; in others pyroxene, scapolite, titanite wollastonite were also observed. From these graphite veins the country rock has been impregnated with the mineral, particularly in the case of the crystalline limestone, and where such impregnation is seen in the mica-gneiss it has been confined essentially to the layers richest in mica, along which the rock breaks easily. Along the contacts of the graphite veins, the neighbouring rocks have suffered alteration with scapolite, apatite, &c., and in places the granular limestone has been converted into a mixture of pyroxene, wollastonite and titanite. Sometimes the rock is so strongly impregnated with silica as to form a rock somewhat similar to quartzite.

Deposits of Buckingham district studied by Prof. Osann.

In connection with this subject Prof. Osann also made a study of the graphite deposits of the Buckingham district, more particularly those belonging to the Walker mine, or as it has been styled Graphite City, and recognized the fact that there were certain points of difference in the occurrence of the mineral at the two localities. Thus in the Buckingham district the mineral is frequently found in veins which cut the plutonic rocks, and he therefore concludes that in such cases the process of the vein formation has been by fumarole action after the cooling or solidifying of the eruptive rock. In this way the presence of the graphite is largely analogous to the occurrence of apatite in the pyroxenes of that district, and both minerals are often associated in the same vein.

In regard to much of the disseminated or flake graphite, found both in the limestone and in certain bands of the gray gneiss, he states that this graphite has been derived from carbon, originally present in the rock itself, and is probably of organic origin.

Foreign materials introduced by contact metamorphism.

As the result of his study of several localities, Prof. Osann comes to the conclusion that minerals have been formed which are essentially the same as one is accustomed to observe in limestones which have undergone contact metamorphism. This portion of the limestone has been penetrated by gases and vapours from the neighbouring eruptive magmas, upon further cooling, perhaps also by solutions, and that in this way the materials foreign to the limestone, especially the silica, have been introduced. Further evidence in support of this theory will be found in his report, Vol. XII, 1899, p. 79.

The rocks of the Buckingham and Lochaber districts are largely gneiss, crystalline limestone and quartzite. These are cut by numerous masses of pyroxene, granite and occasionally by dykes of diabase. Similar rocks are found in the graphite areas of eastern Ontario which are undoubtedly the prolongation westward of the rocks north of the Ottawa, the overlying palæozoic formations concealing them in the intervening Ottawa river basin.

These gneisses and associated altered sedimentary rocks have a general north-north east strike, varying, however, very considerably at different points. As at other places in the area this divergence of strata appears to be often due to the presence of large masses of pyroxenic rocks, and the same features are seen along the Lièvre river in connection with the pyroxenes and gneiss of the apatite mines.

The gneissic bands are often largely composed of sillimanite and are frequently highly ferruginous owing to the weathering out of a certain

amount of contained pyrite. The crystalline limestone occurs as interstratified beds in the gneiss, and forms the highest portion of the Grenville series proper.

The graphite here occurs in several ways:

1. As disseminated flake in the limestone and gneiss and sometimes in the quartzite, pyroxene and even in masses of iron ore as at the Hull iron mines;

2. As lenticular or disconnected masses embedded in the limestone, or near the contact of this rock with eruptive masses, or partly in the limestone and associated gneiss. Sometimes the mineral is in the form of flake but is often associated with considerable deposits of the amorphous variety;

3. In the form of true fissure veins which traverse the gneiss and sometimes the intrusive granite or other eruptive rocks. The mineral in these cases is of the columnar or foliated variety.

Beneficial effect of intrusive rocks.

The beneficial effect upon the presence of graphite exerted by the agency of intrusive rocks was evident during the examination of many of these deposits by the writer in 1893, when it was seen that in all the mining areas this feature was conspicuous. In all cases where there were large bodies of disseminated ore in the gneiss or limestone such were usually closely associated with masses of granite or diorite. From notes furnished me by Mr. H. P. Brumell who was engaged in the graphite industry of the Buckingham district for some years it is evident the same conditions are seen on the property of the North American Graphite Co. He says of the rocks on lot 28, range VI, Buckingham, that 'a series of parallel bands of graphitic gneiss are cut without any throw by a diorite dyke about 50 feet wide which cuts the strata at right angles. To the north of this main dyke is a reticulating system of small diorite eruptions in the neighbourhood of which the beds of ore are materially enriched. Again about 40 chains to the north of the above and in the pits near the mill of the company there occurs an apparent overflow of diorite beneath which cap the richest ore was found. And it may be stated in a general way that where the graphitc gneisses are cut by dykes the percentage of graphite is much higher than elsewhere."

Economic production.

In regard to the economic production of graphite, while as already mentioned many of the fissure deposits are of great purity, the uncertainty of these occurrences is against their profitable exploitation on the large scale. Certain of the veins sometimes reach a thickness in places or between one and two feet, but these large veins are usually

Vein deposits.

short and soon split up into small ones or die out entirely. Among localities where this pure graphite appears to be most abundant, is the property of the Walker Co., where near the line between ranges VII and VIII on lots 21-22, Buckingham, in several of the pits there occur veins ranging in thickness from a few inches up to a foot and a half which have been worked to some extent. Vein graphite is also found on lot 27, range V, in three veins disclosed in a pit, having a thickness of from six inches to two feet. On lots 15-16, range VI, the vein variety also occurs, and on lot 23, range V.

Disseminated flake of greatest economic importance.

The most persistant of the graphite deposits however are those which are found as disseminated flake. In the Buckingham district this variety is found usually in the grey mica gneiss in bands or beds which sometimes have a thickness of from ten to fifteen feet, or in places even more as well as in limestone. In some of these beds the graphite is very thickly distributed and the rock is quite black from its presence, indicating a high percentage of the mineral. Several assays were made by Dr. Hoffmann in the Survey laboratory some years ago which were published in the report for 1876-77 and are as follows : —

A specimen of disseminated ore from lot 28, range VI, Buckingham, owned by the Montreal Plumbago Co., the sample being regarded as a fair average of one of the largest and most extensively worked beds in the area with a breadth of eight feet, gave by assay, graphite 27·518 rock matter, 72·438 per cent. A sample from lot 22, range VI, Buckingham Mining Co., gave graphite 22·385, rock matter, 75·875 per cent. Specimens from lot 20, range VIII, gave graphite 23·798, rock matter 75·026 per cent; and from lot 23, range VI, graphite 30·516, rock matter, 69·349 per cent. In all the above occurrences the amount of disseminated ore appears to be large, and in some the presence of the vein variety is also recognized.

It must not be supposed that all the disseminated ore occurs in beds equally as rich as those just mentioned, but at very many points deposits exist which give amounts of flake from large bodies of ore, which range from 10 to 15 per cent or even higher. These ore beds are quite the equal in richness of any of the deposits worked in New York state.

Other vein deposits.

In addition to the vein deposits already mentioned as occurring in Buckingham, others are found in the Augmentation of Grenville, on lot 3, range II, where there is a reported vein 10 inches thick with disseminated ore, and on lot 1, range VI, as well as at other places in this area. The percentage of graphite from these deposits was found on assay to range from 97.626 to 99.815, thus shewing a

degree of purity quite equal to that found in the best Ceylon or Ticonderoga ore. Concerning the value of the prepared graphite, Dr. Hoffmann states that "in respect to incombustibility the Canadian graphite mayclaim perfect equality with that of the Ceylon; and that, apart from any consideration of proportion and nature of the associated foreign matter, it is in no wise inferior to the latter as a material for the manufacture of crucibles." Regarding the disseminated variety he also says in discussing this subject, that "prepared according to the present process the dressed graphite obtained from beds of disseminated mineral, is apt to contain more or less carbonate of soda and oxide of iron." He however points out that these can be easily removed by a simple process and the graphite be left "with a very small amount of ash, and that of a nature in no wise prejudicial to its application for the purposes under consideration." Rep, 1876-77.

Market affected by uncertain quality of product.

Discussing the nature of these deposits, Mr. J. Fraser Torrance, who spent some months in the graphite district in the study of apatite and other minerals, remarks that the bad reputation of the Canadian graphite on the market abroad is due to the uncertain quality of the article shipped, (Rep. 1882-83, p. 31 J.,) and to the fact that it contained certain impurities pointed out by Dr. Hoffmann as easily removable, but which had not apparently been done by the company that worked the mine; in other words that while certain portions of the mill product were of excellent quality, this excellence was not maintained throughout, so that the purchaser was uncertain as to the exact nature of the material purchased, and in consequence the market demand speedily ceased. In point of fact this statement appears to be clearly borne out in the history of all these mining operations which have been carried on at intervals for many years, since while all authorities are agreed as to the excellent quality of the ore, and to its abundance at many places, the loss of a permanent market has always been attributed to a lack of care in its preparation and proper purification.

Early history of graphite mining.

The early history of graphite mining in the Buckingham district dates back for about 40 years. The first mill of any importance appears to have been erected by the Lochaber Plumbago Co. on the Blanche river, lot 28, range X, Lochaber. The mill was run by water power, and was supplied with a battery of eight stamps and two circular buddles. The ore was stamped in water, and then passed over the buddles and afterwards through the stones and screens, but this part of the process was kept secret. The ore was obtained from several, points in the vicinity and principally from lot 24, range VIII, and lots 23-24, range XI. The ore beds were apparently in crystalline

limestone with bands of grey gneiss, through which were numerous veins irregularly distributed at or near the contact with a heavy dyke of granite, and the thickness of the ore bands was reported to range between 20 and 30 feet, while some of the veins had a breadth of 14 inches. A shaft was sunk on the ore body and several large trenches were made, so that a large amount of ore was raised and sent to the mill which from the first named lot is given as 620 tons (Rep. 1866, pp. 22-23.) On lots 22-23, the mineral occurred as the disseminated variety in a crystalline limestone which in places was black from the abundance of the graphite. The ore bed was reported as from 10 to 12 feet thick, and was worked by open cuts, the contained graphite being stated as about 20 per cent. This was mined to some extent and about 150 tons of the ore were sent to the mill for treatment. Operations have been suspended for many years, and when the locality was visited in 1893, the ruins only of the mill were to be seen.

Two other mills were erected in the early days of the industry, of which one was on the Garrett lot, (on McNaughton Creek), about two miles east of Buckingham, and the third on Fernie creek which is a discharge from the Twin lakes. This last was burned down but the other was abandoned and gradually fell to pieces by decay. No details as to the working capacity of these mills are available.

Walker Mining Co's mills.

These old mills have been supplanted by three new ones which have been in operation at intervals for some years. Of these the mill of the Walker Mining Co., on lot 19, range VIII, Buckingham, appears to have been the first erected about 20 years ago, but the original mill was abandoned and a new one put in operation in 1888 which worked at intervals to 1895, since which time it has practically been idle. The mill was well equipped with crushers, stamps, buddles, stones and screens, worked by a steam engine of 100 horse power, and with a reported capacity of 20 tons of raw material per day of 24 hours, or about three tons of the finished product.

The second mill is on the property of the Buckingham Mining Co. (Pugh & Weartz), lot 26, range VI, and has been in operation at intervals for some fifteen years. The mill of the North American Graphite Co., was erected in 1895, and though largely experimental is said to have a capacity of about two tons of the finished product per day.

The mills of the Walker Co., and of the last named, employ the wet method in the treatment and separation of the graphite, but in the other mill the dry process is employed. This has worked only fairly well, but the details of operation are not available. A modification of this plant is now in operation at the mills of the McConnell mine near

Olivers Ferry, Ont., and the process there is stated to give satisfactory results.

In the wet process the raw material after passing through the crushers goes to the stamp battery where it is crushed in water. Thence it passes to the buddles, then to the millstones, and is finally separated in a series of screens by which the separated flake is graded for the market. In the mill of the North American Graphite Co., lot 28, range VI, an improvement was introduced in the buddling process by which it is claimed greater efficiency is attained by the use of the Brumell separator, whereby a very close separation is achieved at once by the flotation of the dried graphite ore upon the surface of a current of water. After concentration, the method employed is the same as that in use at most of the other mills on the continent, viz., by buhr stones and screens. The product is high grade flake and low grade ground stocks. Details of wet process.

All these mills operate on the disseminated graphite, mostly from that contained in the greyish gneiss, and the columnar form is not considered as being in sufficient quantity to warrant the erection of commercial plants for its treatment owing to the uncertainty attending the deposits of this variety.

From the experience obtained from the running of these several plants it has been clearly established that for all purposes to which graphite is usually applied, with the exception of fine pencil making, the graphite so obtained has been proved eminently suitable. It has also been demonstrated that in properly constructed mills, and with proper care, a very high grade of graphite can be produced from the disseminated ores of the Ottawa district, as is evidenced from the analyses of the finished products made by different reliable assayers.

Much information relating to the extent and richness of the many graphite deposits in this province is given in the earlier reports of the Survey, more especially in the Geology of Canada, 1863, and in Vennor's report for 1873-74, pp. 139-143. In Vol. X, 1897, (pp. 66-73 S.) a very full description is given of the numerous deposits in the Buckingham district, prepared by Mr. A. A. Cole for the Geological Survey, shewing the extent of the ore bodies and the amount of development work done. This is accompanied by a reliable map of the area on which are placed all known outcrops, mill locations, and other points of general interest. Information contained in earlier reports of Geological Survey.

## Graphite in Province of Ontario.

Graphite in Ontario.

The presence of graphite in certain rocks in Ontario was recorded as early as 1846 in Logan's report for the year. The locality first noted was in the township of Westmeath on lot 21, range A., front, near the Ottawa river, the mineral occurring in crystalline limestone, but no work has apparently ever been done here to determine the extent of the deposit which is probably not large.

In Murray's report on the district north of Kingston, 1852, the occurrence of a small vein of only one inch in thickness is reported on Mud lake, township of Loughborough, where it cuts the gneiss of that locality, but this may evidently be regarded as of no economic value.

Referred to in the Geology of Canada.

In the Geology of Canada, 1863, reference is made to its occurrence at several points, among which may be mentioned lot 6, range IX, Loughborough, where it is found in as a bed in limestone with a thickness of from three to eighteen inches, mingled with vitreous quartz, in which portions of pure graphite are imbedded; and on lot 18, range IX, Bedford, also in crystalline limestone, as well as at Bird lake, where it occurs in quartz with crystalline limestone. At neither of these places do the deposits appear to be extensive.

Since the date of these earlier reports deposits of graphite have been found at a number of places, some of which are large and of great commercial importance. In the Report by H. G. Vennor, 1872-73 mention is made of one of these in the township of North Elmsley, lot 21, range VI, about one mile north of Olivers Ferry on the Rideau canal. This was opened and has been worked at intervals by different people for more than thirty years, and at this place probably the first attempts at graphite mining in this province were made.

Important deposit near North Elmsley.

The mineral here occurs in crystalline rocks of the Grenville series, similar in character to those which have been already described in the province of Quebec. At the principal openings the old rocks are capped by horizontal beds of Potsdam sandstone. Where first opened up the graphite was found in a sandy greyish and somewhat decomposed gneiss, quite rusty in places, with beds of quartzite, underlying the crystalline limestone, and the graphite was well disseminated through a belt of considerable extent. The rocks here show the presence of a low anticlinal with low dips to the north-west and south-east.

The earlier mining at this place was carried on the gneissic portion of the formation, and the output was hauled to the shore of the canal,

about one mile distant, where a mill for the separation of the mineral was erected in 1872. This was equipped with stamps, buddles, and sieves or screens, and several grades of the separated flake were produced, of which the finest was used for electrotyping, a second for lubricating purposes, a third for pencil stock, a fourth for stove polish, and a fifth for foundry facings. The amount of mineral in the rock at the mine was held to run from 10 to 20 per cent, and was taken from a pit 300 to 400 feet long by 200 feet wide with a depth of about 20 feet. After working for several years the mill was apparently closed down in 1875-76.

Worked by Mr. J. Fraser Torrance.

The property was later worked for a time in 1893 by Mr. J. Fraser Torrance, but this was apparently not attended with much success owing to reasons not stated. The details of the first company's operations are given at length in the Report of the Bureau of Mines, Ont. for 1896, (pp. 35-36).

The property apparently lay idle till 1901 when Dr. R. A. Pyne of Toronto secured the diamond drill of the Ontario Government and bored several holes to test the depth and extent of this deposit. In this work four holes were sunk to the depths respectively of 130, 140, 64, and 100 feet. The borings shewed the presence of graphite of good quality and in large quantity. In the first boring the log showed 32 feet of graphite, the remainder of the hole being in an altered granite and limestone to the full depth of the hole; No. 3 shewed two feet of altered granite mixed with graphite, the remainder of the hole being in limestone; and in No. 4, there was found 30 feet of rich ore, the rest being lean. The nature of the "altered granite" is not stated and it may include certain of the bands of gneiss usually associated with the limestones of the formation.

Property secured by Mr. Rinaldo McConnell.

No attempt at mining is recorded by Dr. Pyne, but the property was secured shortly after by Mr. Rinaldo McConnell of Ottawa who also tested the property with the government drill preparatory to mining, which was commenced in the spring of 1902, the value of the property having been well ascertained, and the presence of large ore bodies determined, which in graphite contents compare very favourably with those which have been mined in the Buckingham district of Quebec. Surface shewings were also found on lot 22, range VI, Burgess, but the actual value is not yet known.

The work of Mr. McConnell included the erection of a mill at the village of Port Elmsley, or rather the alteration of an old grinding mill which had been built at that place on the River Tay, some years before. Here there is a water power with a seven foot head which furnishes, with a Dodge turbine, about 50 horse power.

Mining operations.

Mining began at once, and when visited in Sept. 1903 there was an excavation of about 250 feet in length with a width varying from 8 to 14 feet and a depth from 10 to 15 feet. The old workings were abandoned and the new mine is several hundred yards to the south-west, situated on a bed of limestone which overlies the gneiss. This limestone contains thin rusty bands of sillimanite gneiss, and both are strongly charged with flake, some of the layers being quite black, so that the original composition of the rock is scarcely recognized. The dips are generally from 5 to 10 degrees, but at the north east end of the main trench the strata are inclined sharply to the north-west at an angle of 40 degrees. The openings are made along the low crown of the anticline, and no granite was seen on the surface at the mine itself, but there are small outcrops of a rather coarsely crystalline gabbro in the immediate vicinity. Granite ledges, however, show a short distance south-east of the pits and have been cut in the borings. The graphite appears to be all of the disseminated variety and no veins of the columnar were noticed. In the bottom of the trenches the ore seemed to be quite as rich as near the surface.

Treatment of ore.

The ore which is at present mined in the limestone, after being hauled to the mill a distance of nearly three miles, is first roasted in an ordinary kiln, sufficiently to drive off the contained moisture, but not enough to calcine the rock itself From the roaster it passes on a short track to the crusher, where it is broken to a uniform half inch-size, two sets of crushers being used. Thence it passes through a series of steel rolls which further reduce the ore to $\frac{1}{16}$ inch size. Then to the jigs which are of the pneumatic type, four in number and from the jigs the separated ore passes to the millstones where it is ground; and passing thence to the screens, it is there separated into four grades. The process of separation is apparently by the dry method throughout, and the whole routine from the preliminary roasting to the final bolting is automatic. The present capacity of the mill is about one ton and a half per hour, and the yield of graphite from the rock is placed at about 10 per cent. The dry process in this plant is claimed to work very satisfactorily. The mill is located a mile and half from Elmsley station on the Canadian Pacific railway.

Borings.

In the investigations on this area by Mr. Torrance, in 1893, borings were also made at a number of places on lots 21 and 22, range VI. and one on lot 23 of range VII. These borings reached depths of from 50 to 100 feet and the presence of the graphite bearing rock was reported as continuous to the bottom of the test holes while in some of the cores the mineral apatite was found.

Other deposits.

Deposits of graphite were observed in 1896 in the township of Blythfield on lots 13 and 14, range IV, near the bank of the Madawaska river, a short distance above the High Falls, on land owned by Mr. James Bailey. These were opened to a small extent, and the mineral occurs in a greyish rusty gneiss associated with granite and greenish-grey pyroxene. The disseminated ore is partly flake and partly amorphous. The gneiss is in places highly garnetiferous and no limestone was seen at the locality where the graphite is exposed.

Among other places where the presence of this mineral is recorded in Ontario may be mentioned lot 13, range VIII, township of Marmora, where it is said to occur in considerable abundance, though no record of development work is to hand. The graphite from this place was examined in the laboratory of the Geological Survey and is of the amorphous variety, containing a small amount of finely disseminated pyrite, and gave on analysis, graphite 72·13, foreign matter, 27·86 per cent. Annual Report, Geol. Surv. Can., Vol. VII (N.S.) 1894, p. II R.

It has also been reported as occurring in the township of Faraday, on lot 13, range I, and by Dr. Barlow in the townships of Dysart and Glamorgan, where it is somewhat widely distributed in the limestone and upper gneiss of the Grenville series, (Summary Report, 1896, p. 53) but apparently no development work has yet been attempted in this area.

In the township of Darling also a small deposit of the amorphous variety has been located near Tatlock, but the value has not been definitely determined, though from surface indications the amount of the mineral does not appear to be large.

Deposit in Denbigh township.

In Addington county, township of Denbigh, on lot 34, range VIII, a deposit of graphite was located some years ago and samples were examined by this Department. The mineral occurred in layers and patches in a calcareo-siliceous gangue, and on assay was found to contain 51·67 per cent graphite. It appears to be of the amorphous variety.

Worked by Mr. J. G,

Recently this property has been opened up by Mr. J. G. Allan of Hamilton, Ont., who has furnished me some notes as to the nature of the work lately done. Mr. Allan says operations were commenced about the beginning of December, 1902, and a number of tons were taken out that month. In 1903 the mine was worked for about five months and 150 tons mined. The shaft is about 45 feet deep and well timbered. The material is somewhat mixed with quartz, but runs

about 50 per cent graphite and is improving in quality at lower depths. There are two veins which are widening and look as if they would meet below.

The following is the result of assay of this ore by Thomas Heys and Son of Toronto.

| | |
|---|---|
| Graphite | 76·12 |
| Silica | 5·70 |
| Ox. Iron | 1·28 |
| Carb. lime | 16·20 |
| Carb. mag | 0·70 |

A similar occurrence is found on lot 1, range VIII, of Ashby which is the lot adjoining on the west. At present shipping facilities are bad, as the distance to railway is between 30 and 40 miles, but there appears to be a considerable amount of good ore in this area.

Black Donald mine.

With the exception of the mine at Olivers Ferry and that just mentioned the only other property at present being operated is that known as the Black Donald mine in the township of Brougham on the west end of Whitefish lake the property of the Ontario Graphite Co. It is situated on lots 16, 17, 18 and 19, range III.

Work was done on this area in 1895-96, and when examined in August of the latter year had been suspended. The ore-body was apparently large and was uncovered along its course about south-west from the shore of the lake for about 150 feet, with an exposed surface breadth of about 10 feet. The rocks around the lake are largely crystalline limestone associated with rusty gneiss and masses of granite. The strike of the former is N. 55° to 60° E. with a south-east dip of 60 degrees. The graphite where exposed appeared to be in bed form, underlaid by a hard whitish granite or pegmatite composed of quartz and felspar, and the ore body occurred on both sides of the granite dyke, continuing out under the waters of the lake. Graphite scales were also observed in certain portions of the granite, but it did not seem to be largely disseminated in the gneissic portion. A certain amount of pyrite was seen along the contact of the granite in the altered portion of the gneiss.

Nature of deposit.

The general impression as to the graphite at that time was that it formed a large body of fairly pure mineral well worth development.

This property was shortly after opened up extensively. A mill was erected in Ottawa to treat the ore chemically, owing apparently to the somewhat large amount of calcite which it contained, and the ore was

brought in from the mine for treatment. This mill was operated for some months and then closed down.

Worked by Ontario Graphite Co.

As to the mine development, the Ontario Graphite Co. began operations on a somewhat large scale, the details of which can be given from the reports of The Bureau of Mines of Ontario.

Section of bore hole.

Thus in the report for 1895, it is stated that the deposit has a length of 300 feet, and four cross cuts made at inter-vals of 50 feet shew widths of the vein or bed as respectively 12, 17, 18 and 24 feet. The place was bored with a diamond drill with the following result. One bore on the shore of the lake passed through 39 feet of graphite, succeeded downward by six and a half feet of mixed limestone and graphite; this again by 10 feet of graphite; then seven feet of mixed limestone and graphite, one foot and a half graphite and two feet felspar and quartz. In another hole further removed from the shore there was graphite 15 feet, graphite and limestone seven feet and graphite six feet.

Deposit not uniform throughout

The deposit is not homogeneous throughout. The calcite occurs in nests and irregular pockets or masses, but containing also irregularly disseminated graphite and minute scales of mica. The quality of the mineral is somewhat lowered by the presence of the calcite in such a degree as to render portion of the deposit useless. An assay by Dr. J. T. Donald of Montreal, gave graphite 84·12, but the percentage varies in different specimens from 49 to 85. The graphite has a greyish aspect, is very hard, and occurs both as flake and amorphous. It is partly embedded, in gneiss in the manner of a vein with a strike north-east and south-west.

In the report for 1901, (Mining Bureau of Ont.) it is stated that the company known as the Ontario Graphite Co. was organized in 1896. The workings consisted of open cuts and a shaft 80 feet deep, with a drift to the north-east from the bottom of 150 feet which extended under the lake. The vein is vertical, and at the bottom has a width of 22 feet with enclosing walls of crystalline limestone. An analysis by the Crescent Steel Co. gave graphitic carbon, 84·06, silica, 3·90, lime 10·05.

Steam plant replaced by electric.

In the report for 1902, Bureau of Mines), further details are given. The steam plant was replaced by an electric plant, operated by power generated at the Mountain Chute on the Madawaska river, two miles and a half south-east of the mine. This plant furnishes sufficient power for working the mine including lighting and heating, and for the graphite refinery which is erected close to the mine on the shore of the

lake. The main shaft is 10 x 12 feet, vertical, and 80 feet deep. The main level northeast was extended to 200 feet out under the lake and to the south-west for 24 feet. The former was stoped out 50 feet high for 120 feet, and 30 feet for the remaining 80 feet. The latter was stoped out 16 feet high for the full length, the stopes being from 8 to 22 feet wide or averaging 13 feet. A 20 foot collar extends down the shaft with a 50 foot open head frame.

Development.

South-west from the shaft the vein was located by an open cut for 135 feet, 12 feet wide and 39 feet deep. Fifty-four feet south of this is another open cut, 10 feet wide and 50 feet long; and 50 feet beyond this a vertical shaft was sunk to a depth of 49 feet. Beyond this cross cuts uncovered the vein for several hundred feet. In 1901 three diamond drill holes were sunk from the bottom of the 80 foot shaft, finding graphite at a depth of 122 feet from the surface, where a hard flinty rock stopped the further progress of the drilling.

The surface exposures shew the rock to be a white limestone in which the graphite vein or bed is located, with a thickness varying from seven to twenty-two feet, averaging about 14 feet of clean ore or graphite with 15 to 20 per cent of rock matter. For two to three feet back the walls are of schistose limestone, carrying thickly disseminated graphite flake. Beyond this the graphite is regarded as sufficiently abundant to make a milling ore over a width of 40 feet where worked. In the central portion the mineral occurs both as flake and in the crystalline form.

Development seriously affected by break in roof of mine.

In the autumn of 1902 a break occurred in the roof of the drift which extended under the lake so that the water with the marl which formed the lake-bed was admitted and flooded all the workings connected with the main shaft. This accident has, for a time seriously affected further development, but work has since been carried on the western portion of the deposit, the results of which have not yet appeared.

This place is distant from the Kingston and Pembroke railway at Calabogie by winter road about 12 miles, but the regular road is fully twice as long. About 2,200 tons ore were extracted in 1901, most of which was shipped.

Extent of ore body.

The amount of ore in the extension of the deposit west of the main shaft appears to be quite as large as in the eastern or lake portion of the ore body, and in its extension from the west shaft is reported as having at one place a thickness of 46 feet, which however may be only a local development, The mine is well equipped with appliances

for raising and separating the ore and the output from the refinery is produced in nine grades, of which the first four are composed of flake or crystalline graphite of different sizes and with a purity of from 93 to 96 per cent carbon; the next is a mixture of flake and amorphous running about 78 per cent carbon; and the last four are amorphous powders of varying degrees of purity from 54 to 62 per cent. For details of mill, &c., see Bureau of Mines report, Ont., 1903, pp. 132-34.

Other occurrences of graphite are recorded, as in South Canonto on the second range, lot not mentioned, where a small amount of work has been done. Also on lot 2, range VI, Bedford; Dungannon, lot 28, XIII; Loughborough, lot 6, range IX; North Burgess, lot 10, range I; North Elmsley, lot 7, range IX; and at Parry Sound; see Minerals of Ontario, Bureau of Mines, 1900, page 199.

In regard to the western portions of the Dominion including the Rocky mountain area and Pacific coast slopes no records of graphite deposits of economic importance have yet been recorded.

## Statistics.

Production.

The first records of production given in the Geological Survey Reports of the Section of Mines, are for the year 1886, the output for that year being stated as 500 tons with a value of $4,000. Since that date for about ten years the figures fluctuate and in 1893-4 the output was practically nil. There was a marked revival of the industry in 1895, and since that time the output has increased regularly to 1901, when it reached 2210 tons valued at $37,780. Owing to the closing of one of the principal mines for a time the output for 1902 declined to 1095 tons valued at $28,300.

The principal producers during the last year mentioned were the Canada Paint Co. of Fairville, N. B., the North American Graphite Co. of Buckingham, Que.; and the Ontario Graphite Co. of Ontario, operating at Whitefish lake, Brougham township.

The value of graphite in the crude and as manufactured imported in the year 1901 into Canada, was $77,893 as under.

| | |
|---|---|
| Plumbago, not ground | $ 2,357 |
| Black lead | 25,346 |
| Plumbago, ground and manufactured, crucibles, &c. | 49,890 |
| | $77,893 |

In 1902 this amount slightly declined, the figures being for

| | |
|---|---|
| Plumbago, not ground | $ 3,649 |
| Black lead | 20,467 |
| Plumbago, ground and manufactured, crucibles, &c. | 43,656 |
| | $67,772 |

NATURAL SCIENCE
N
26
3
903
.11

✓ 880

GEOLOGICAL SURVEY OF CANADA
ROBERT BELL, M.D., D.Sc. (CANTAB.), LL.D., F.R.S.

# MINERAL RESOURCES OF CANADA

---

## BULLETIN

ON

# PEAT

BY

R. CHALMERS, LL.D.

OTTAWA
PRINTED BY S. E. DAWSON, PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1904

No. 880

THE UNIVERSITY OF MICHIGAN LIBRARIES

Natural Science
Library
TN
226
.A3
1903
V.11

# PEAT IN CANADA

By R. CHALMERS, LL.D.

## *Definition and origin.*

Origin of name.

The origin of the name peat is obscure, but it is supposed to be of North German or Anglo-Saxon extraction from a word signifying bog or pond. As employed at present the term includes a number of substances of vegetable production, though in its restricted sense it is generally applied to the mosses of the genera *Sphagnum*, *Hypnum*, etc., when found growing together in a dense mass forming a bog in situations where the drainage is imperfect. These mosses, particularly the *sphagna*, cannot live except in clear, standing water and in a crowded condition. Their peculiar mode of growth, increasing the length of the stems upwards year after year, while dying at the roots, perpetuates their existence and raises the surface of the bogs of which they form part. The *sphagna* hold water like a sponge, and small pools are occasionally seen in the undrained parts of the moors when these are large. The water absorbed by the mosses, of which they contain 85 to 95 per cent by weight, is wholly due to the rainfall, the growth of the *sphagna* depending upon their complete saturation. The part of the bog retaining the moisture all the year ronnd, or that from which there is the least drainage, is usually higher than the margin. Around the periphery where there is more or less seepage, or escape of the contained water, the mosses are checked in their growth and often die, the bogs in such places exhibiting dead peat. This destruction of the life of the mosses is, however, more apparent in the interior of the country where the summers are hotter and the air drier than it is along the coasts. Their healthy condition depends so much on an ample rainfall and cool summers that in dry years considerable quantities are killed, or suffer a serious check in their growth; hence the existence of so much dead peat in some portions of the interior. Drought and a diminished rainfall are inimical to the growth of peat bogs; thus the central and undrained parts of the larger bogs are often higher than the margins, because these are the last to become drained out.

Mode of growth of the mosses.

Conditions of their existence.

Every peat bog, though composed of a variety of vegetable forms, mosses, herbaceous plants, shrubs and trees, is a unit of itself, a concrete whole, a product of the climate and soil, its life closely related to these, and affected by every change to which they are subject.

## GEOLOGY AND PHYSICAL FEATURES OF THE PEAT BOGS.

Age of the peat bogs.

The greater number of the peat bogs in Canada belong to the Recent or Prehistoric period, or to the period intervening between the ice age, so-called, and the present, and are indeed still in process of growth. Peat of interglacial and probably pre-glacial times has however, been discovered. At River Inhabitants, Cape Breton, a bed of this material was found under boulder-clay.* At the head of Chignecto bay, in Cumberland basin in the bay of Fundy, peat has been met with under recent deposits, one of the beds at Aulac station, Intercolonial railway, twenty feet thick, occurring under eighty feet of marsh mud.* In a number of places around the Strait of Northumberland the peat bogs lie in basins which are at least five to ten feet below the level of high tides. If these basins were emptied of peat they would now be occupied by the sea. As the mosses which principally compose the peat cannot grow in salt water, it is inferred that these basins must have been above the reach of the sea when the peat first began to grow in them, and hence there must have a slight sinking of the land or a rising of the sea since. It is probable that the bogs along the coasts commenced to form as soon as the land emerged from beneath the sea in post-glacial time, while those upon the higher grounds and in the interior are older and have, perhaps been in existence since the close of the glacial period. Evidently they did not all originate at the same time, but at different stages, as the mosses composing them found a suitable habitat, and the climatic conditions, drainage, etc., became favourable to their development. Nearly all the peat mosses in Canada seem to be still growing and increasing in area and depth.

The central parts of nearly all the larger bogs are treeless, or have only a few stunted forms of black spruce and hacmatac upon them. Around the borders there is a thicker growth, when the bog is in its natural state. In some countries attempts have been made to show that the moors, which have thus lost their forest covering, became denuded because of a change in the climate, or in the elevation of the land, or in some other manner since the peat began to grow. But the facts obtained by the writer in the study of these formations for

* Acadian Geology, 2nd Ed. p. 68.

†Annual Report, Geol. Sur. Can. Vol. VII, p. 129 M.

many years do not favour this hypothesis as regards our Canadian peat bogs, and another and more natural explanation has suggested itself. For example, it was found that the bogs occur at all stages of growth and development from the incipient moss only a few inches in thickness to others twenty or thirty feet deep covering thousands of acres. The younger peat mosses have, in their natural state, generally a forest growth upon them composed of much larger trees than are found upon the older bogs. But as the mosses continue to grow and the bog to increase in thickness the trees gradually die, first those in the centre, the area of dead and stunted trees widening as the bog develops. After a time the dead trees fall and disappear from view under the growing moss, the central part of the bog especially becoming treeless first, but the roots and stumps and sometimes portions of the trunks are preserved by the antiseptic properties of the peat moss, and are often found in a sound condition and occasionally with the bark upon them. From these facts it would appear, that the killing of the trees and the deforestation referred to is simply a result of the growth of the mosses which swathe their roots and the base of their trunks in such a manner as to check the circulation and eventually destroy them. And as the bog grows and thickens this treeless area expands. All this may occur without any change of climate, or of the the level of the land, but simply from the natural growth of the *sphagna*.

Causes of treeless condition.

Though so many of our peat beds occupy shallow basins, few, if any, seem to have originated in the growth of mosses around or upon the margins of ponds or small lakes as in some countries. Peat *sphagnum* flourishes best in the pure, cold, static waters absorbed by them. The fact that in the bottom of nearly all our peat bogs, roots and stumps of trees and shrubs indigenous to the soil are found, would indicate that they did not begin to grow in or upon bodies of water which had any permanence, but merely in hollows occupied by water occasionally, or at certain seasons of the year.

## MOSSES AND OTHER PLANTS OCCURRING IN PEAT BOGS.

In Prof. J. Macoun's Catalogue of Canadian Plants, Part VI*, the mosses which occur in peats bogs in Canada are enumerated, showing there are about thirty species all told, with a large number of varieties. Of these about twenty belong to the genus *Sphagnum* and five to *Hypnum*, the remainder being species of *Polytricum*, *Dicranum*,

Mosses and other plants constituting the peat bogs.

* Catalogue of Canadian Plants, Geol. Surv. Can., part. VI, Musci.

etc. All but a few of these are comparatively rare, and *Sphagnum acutifolium*, *S. fuscum* in two varieties, *S. Gingenshonii*, *S. imbricatum*, and two or three others seem to constitute the great bulk of the bogs. Besides the mosses the bogs are often covered, more or less thickly in places etc, with ericaceous plants, stunted black spruce, hackmatac, etc., which appear to have grown in certain parts throughout their whole existence from their incipient stages. These are still found living in spots near the margin as well as upon the drier parts. The species of ericaceous plants most common in the bogs are *Vaccinium macrocarpa*, *V. palustris*, *Guylussacia dumoza*, *Cassandra calyculata*, *Ledum*, *Latifolium*, *Kalmia*, two species, *Rubus Chamæmorus*, etc. There are also the following herbaceous forms namely, *Scirpus*, *Eriophorum*, *Carices*, and other sedges and grasses, besides *Sarracenia*, *Drosera*, *Solidago*, *Arethusa*, etc.

Sequence of the beds in the bogs.

The bogs are usually constituted of three or four different kinds of peat, namely (1) The yellow, greenish, or reddish living mosses in the upper part, which generally form a layer only a few inches in thickness; (2) the dead and dying roots of these mosses, constituting a dark brown, spongy, fibrous, coherent bed of greater or less thickness; (3) a blackish, partially decomposed stratum, more brittle than the last, the mosses having evidently undergone more decay, but still sufficiently tenaceous to form turf, and (4) a black layer of variable thickness, consisting largely of decomposed moss, etc., and holding stumps, roots and other portions of trees and shrubs, also more or less decayed. The last two generally graduate into each other. Occasionally the stumps and roots penetrate the underlying soil, but oftener appear as if spread out upon its surface.

Rate of growth.

The growth of peat bogs under favourable conditions is supposed to be tolerably rapid; but this depends largely upon local conditions of mean temperature throughout the summers, and upon the precipitation. No data respecting the rate of growth of the peat bogs are available in Canada; but in Europe some approximate measurements have been made.*

* In the valley of the Somme, in France, 3 feet of peat grew, in from 30 to 40 years. On a moor in Hanover a layer of peat from 4 to 6 feet thick formed in about 30 years. Near the lake of Constance a bed of 3 to 4 feet grew in 24 years. Among the Danish mosses a period of 250 to 300 years has been required to produce a layer 10 feet thick. Much must depend upon the climate. slope, drainage and soil. Sir A. Geikie, Text Book of Geology, 3rd. ed. p. 443.

## RAISED PEAT BOGS.

### *(Hochmore of Northern Europe.)*

Causes of raised peat bogs.

Reference has been made on a previous page to the fact that a number of the largest and most recently-formed bogs are raised in the centre, or some part distant from the border, above the general level, and a tentative explanation was suggested regarding the causes of this phenomenon. Raised bogs are common in Canada, especially those in a living state. All the dead bogs which the writer has seen however, are flat. In the list given in succeeding pages, those which may be classified as 'raised' are specified and the approximate elevation of the raised portion is sometimes noted. These appear to be exactly similar to the 'raised bogs' of European countries, particularly of Germany. The Canadian bogs are, however, not raised throughout the whole area of each, but have only a part occupying a higher position, and this is generally in the centre, or in some other part at a distance from the margin. The raised part always contains more water than the marginal or lower part, and the mosses are invariably in a living condition, and yellow or reddish to a considerable depth, whereas in the lower peripheral portion they are usually partially or wholly dead. By the words 'living condition' is, of course, meant the uppermost part of the peat moss, for in all bogs the peat is dead, or has ceased growing below the uppermost two or three feet. In the 'raised' bogs, however, the fibres or stalks of the living *sphagna* are much longer than in the lower parts, many being found several feet in length. This part of a bog always contains the cleanest and best moss for economic purposes, whereas in those which are dead the fibres, or stems of the *sphagna* are dark brown and undergoing decomposition.

Water in bogs due to the rain fall.

As stated on a former page the water with which the mosses are saturated even in the very highest parts of the 'raised bogs' is altogether due to the precipitation, the mosses acting as a sponge, and retaining it principally because there is little or no seepage or drainage from them. The fact of the mosses in this part absorbing all the rainfall and retaining it so tenaciously up to the point of complete saturation renders this portion of the bog a more congenial habitat for them than the margin, and therefore, the mosses grow more rapidly and attain a greater height there. Some portion of the water held in these higher or 'raised' parts of bogs may be due to capillarity; but it seems more probable that it is all due to the rain-fall.*

* See paper by Prof. W. F. Ganong on 'Raised Peat Bogs' of New-Brunswick, Trans. Royal Soc. of Can. (2nd series) 1897-98 Vol. III, Sec. IV.

Further, the facts show that the extent and the elevation of the raised portions of the peat bogs are very closely related and dependent upon the extent and depth of the whole bog, that is, the larger the bog the higher and wider is the undrained or 'raised' part, and the smaller it is the less height will the raised portion attain.

Where largest peat bogs are found in Canada.

The peat beds with raised centres usually occur in places where the humidity is great and the summer temperature low. As we would naturally expect they are best developed near the coasts of Eastern Canada and of James bay and Hudson bay. Whenever a change takes place in their local surroundings and conditions, such as the clearing away of the forest, or in the draining and cultivating of any part of the bogs, the tendency of the 'raised' portions is to settle down. These changed conditions cause a seepage of the water contained in the bog as a whole, and in some cases a greater amount of evaporation, which affect its central raised part as well as the margin.

## DISTRIBUTION OF PEAT IN CANADA.

Distribution of peat in Canada.

The geographical range of the peat mosses in the northern hemisphere is now tolerably well known. In North America they are found to have developed best within a belt or zone lying between the mean annual isotherm of 55 degrees Fahr. and the northern limit of trees, reaching their greatest extent in the more humid portions of this zone, and where the summer temperature is low. A line drawn from the Atlantic Coast in New Jersey through northern Pennsylvania, Ohio, North Indiana and North Illinois, central Wisconsin and Eastern Minnesota will roughly include the southern and western limits of the peat mosses so abundant in Eastern Canada, though local beds doubtless exist to the south of this. The boundary referred to passes into Canada through Western Manitoba, and crosses the Great Plains north of the International line. From Alberta westward it curves to the south-west, passing through south-eastern British Columbia re-crossing the International line, and entering the State of Washington, U,S.A. North of this limit there is an almost incalculable amount of peat between the Atlantic and the Pacific, much of it still unknown, as many of the early explorers paid little attention to peat beds. The largest bogs known lie east of the Great Plains in the James and Hudson bay region and in Ontario and Quebec. Peat has been noted by Dr. Bell as far North as Churchill river, and Mr. J. B. Tyrrell found it at Daly lake at the southern border of the Barren Grounds. It has also been observed by Dr. Bell, and Messrs. W. J. Wilson, D. B. Dowling

and Wm. McInnes in northern Ontario and easthern Kèwatin in immense areas and by Mr. E. B. Borron in the Moose river basin. Besides the peat occurring in this region it has been found in Saskatchewan, Athabasca, northern Alberta and British Columbia west of the Okanagan, also in the Yukon territory, where it bears the name of 'tundra'. In most of the territories as well as in Manitoba and northern Ontario the bogs are generally known as 'muskegs'.

## Localities of Peat Bogs.

### NOVA SCOTIA AND CAPE BRETON.

Peat in Nova Scotia and Cape Breton.

1. On the north peninsula of Cape Breton, midway between the east and west shores, and on the watershed at the heads of the rivers there are a number of peat bogs the total area of which is computed at about 100 square miles ; depth from 3 to 5 feet.

2. In Richmond and Cape Breton counties between Loch Lomond and Mira, peat bogs also cover an area not less than 70 square miles; depth 3 to 10 feet.

3. South of Mabou there is a bog half a mile in diameter and 3 feet deep.

4. Between the Strait of Canso and Guysborough, several small bogs occur; total area probably 50 square miles, approximate depth 5 to 15 feet.

5. Two miles south of Smithfield, P.O., Guysborough county, there is a bog $\frac{3}{4}$ of a mile long and $\frac{1}{2}$ mile wide. Depth from 10 to 12 feet, thinning out to the margin.

6. Along Liscombe river, in the same county, several peat bogs were seen the largest being $1\frac{3}{4}$ by $1\frac{1}{2}$ miles; depth 2 to 10 feet; also Taylor's bog, East branch, $1\frac{1}{2}$ by $\frac{3}{4}$ of a mile in extent; depth in centre 10 feet or more.

7. Several small bogs occur near the last, about the headwaters of Sheet Harbour river; area and thickness not ascertained; but from 5 to 10 square miles; thickness 5 to 10 feet.

8. About the headwaters of Tangier and Ship Harbour rivers, bogs comprising 300 to 400 acres of peat occur ; depth 5 to 15 feet.

9. In Queens and Shelburne counties from 400 to 500 acres of peat bogs have been noted, with a probable depth of from 5 to 20 feet.

10. The Aylesford or Cariboo bog, in the Annapolis valley, has been reduced by reclaiming and draining it to an area of about $1\frac{1}{2}$ miles long by $\frac{3}{4}$ of a mile wide. Depth from 1 to 10 feet.

11. The Savannahs, near Clyde river, in Shelburne, have been referred to by Dawson in Acadian Geology, but nothing is said by him regarding their area and depth.

12. Peat bogs were noted about the headwaters of Shoulie and Sand rivers, and in a number of other places in Cumberland county, but the area and depth are not known.

13. At the head of Missaquash river and bordering the lakes which exist there, peat beds occur. These are partly on the Nova Scotia side of the provincial boundary, and partly on the New Brunswick side. The approximate length is about three miles and the width a mile, including the lakes. Since my examination of the region I have learned that these bogs, and the salt marshes bordering them on the south-west, have been largely reclaimed and converted into arable land.

## PRINCE EDWARD ISLAND.

Peat bogs in P. E. island.

The peat bogs of Prince Edward island are shown on sheet No. 5 S.W., surface geology, New Brunswick series, and the area of each approximately delineated. They were described by Sir J. W. Dawson and Prof. B. J. Harrington in 1871, * and occur along the shores of Richmond and Cascumpeque bays.

14. At Black Bank, east of Stephens cove, Cascumpeque bay, there is a bog about three-fourths of a mile long and of nearly equal width; area 350 to 400 acres. The depth is 10 to 12 feet along the shore, the peat resting directly on white sand. Dr. Harrington calculates there are 1,777,248 tons of peat in this turbary. It is highest in the centre and devoid of trees; and the bottom layer is full of roots, trunks and branches in a tolerably good state of preservation. These roots, apparently *in situ*, were observed in places to be about two feet below high water mark. Erosion by the sea is rapidly reducing it. A Mr. Tuplin, who lives in the vicinity, informed us that about five feet is worn off the face of the bog every year.

15. Just west of Stephens cove another bog occurs, covering an area of nearly a mile lengthwise and having approximately the same width, containnig upwards of 500 acres. It is also in a living condition, is

*The Geological Structure and Mineral Resources of Prince Edward Island, by Sir J. W. Dawson, and Dr. B. J. Harrington, 1871.

highest in the centre and without trees. The depth of the moss is from 10 to 15 feet, and the quality is excellent. Messrs. Dawson and Harrington did not examine this bog.

16. A peat bog situated on the northwest side of Richmond bay called the Squirrel Creek bog by Dr. Harrington, has an area of about 800 acres, though the workable portion is not more than 500 acres. Dr. Harrington calculated that it contained 500,000 tons of air-dried peat. The bog is also raised in the centre and destitute of trees. The depth varies from 4 or 5 feet around the border to 11 or 12 feet in the centre. The peat is of good quality most of it being fibrous turf. As remarked by Dr. Harrington "the higher portion of the bog is much wetter than the lower part around the border, and here and there were little ponds containing water plants. The bottom of the ponds could not be reached with a rod more than 12 feet long."

17. At Lennox Island, Richmond Bay, there is a strip of peat on the northeast side facing the sea. It appears to be undergoing rapid erosion, the bank being constantly worn away by the waves, and at high tide the water comes to within three feet of the top, the whole thickness of the bog being about 7 feet. At low water mark the roots and stumps of trees were seen in the bottom of the peat moss. The area of this bog is about 50 acres. It is composed of clean *sphagnum*, slightly decomposed in places in the upper part, and of fibrous peat beneath.

18. Near Portage station, P.E.I. railway, there is a peat bog covering probably about 100 acres. Depth 8 to 10 feet.

19. Halfway between Miscouche and Nicholas stations another was noted having about the same area and depth.

## NEW BRUNSWICK.

Localities of peat bogs in New Brunswick.

The peat bogs of this province were examined and studied by the writer during the investigation of the surface geology between 1882 and 1900. They are nearly all shown on the maps of the surface geology published by the Geological Survey and are briefly described in the reports which accompany these. Little or nothing has been done towards utilizing the great moss bogs which this province contains, wood being still abundant and cheap, and coal obtainable from the Nova Scotia mines at a moderate price.

20. In Charlotte county there are a great number of bogs, as it borders the Bay of Fundy and its climate is humid and comparatively cool. Commencing in the western part small peat bogs were observed

in the following places:—(1) At Moannes stream; (2) south of Basswood ridge; (3) along the old Woodstock road near York county line; (4) near Barber dam; (5) at Lynnfield, 3 miles long and ½ to ¾ miles wide; (6) near Watt Junction, C. P. railway (7) between Watt Junction and St. Stephen, several bogs, the largest at Meadow station, ¾ of a mile long by half a mile wide; (8) near the head of Waweig river, length about 2 miles, width ¼ to ½ a mile; (9) west of a branch of same river, near Shore Line railway, about ½ a mile in diameter; (10) east of Riordan's Corner, 1 mile by ¼ mile; (11) between Pennfield Ridge and Seeley's Cove, about a mile from last mentioned place; about ½ a mile long by 150 yards to ¼ of a mile wide; (a raised bog); (12) at Little Popelogan river, near Shore Line railway, fully 2 miles long by ½ a mile wide, occupying several small basins. (13) On road from Lepreaux village to Point Lepreaux about 2 miles from Shore Line railway, about a mile long and ¼ to ½ a mile wide; (14) several small bogs on east side of Lepreaux river, north of railway, probably a ¼ of a mile in diamater more or less; (15) north of Musquash harbour, and apparently occupying the old valley of discharge of Ludgate and Spruce lakes. Area about 450 acres. Some years ago buildings and machinery were erected here for the preparation of moss litter, but they were destroyed by fire and operations have not been resumed. The average depth of all these peat bogs is from 5 to 10 feet, but a few, notably those at Musquash and Lepreaux, are 15 feet or more in the deepest parts.

21. Peat bogs of some extent occur at the Mispec barrens, St. John county, but the area and depth were not ascertained.

22. In Sunbury county a large peat bog occurs at the head of Little river. It is surrounded by forest and is a favourite resort for moose and deer. Great quantities of cranberries grow upon it. Other peat bogs are reported to exist in that tract of wooded country lying between Canaan and Salmon rivers, tributaries of the St. John.

23. In York county as in Charlotte, there are a number of bogs, most of these also small. (1) Along the St. Andrews and Woodstock branch of the C. P. railway, from the southern boundary of this county northward to Canterbury station, several were noted, and others east ward in the vicinity of Magaguadavic lake. (2) A peat area occurs along the Pokiok river, west of the settlement of the same name. (3) A bog lies at the head of the Mactaquac river, west of Staples settlement. (4) Between Howland ridge, near Millville, and Lawrence Peak, near Becaguimic lake there is a long bog containing excellent *sphagnum* moss.

24. In Westmorland county two or three miles north of Canaan station, Intercolonial railway, a bed of peat about 2 miles long and from ¼ to ½ a mile wide occurs; depth 5 to 10 feet.

25. In Kent county two well developed peat bogs lie on the north side of the Kent Northern railway, from 3 to 6 miles west of Kingston or Rexton, as it is now called. The one nearest the town is 1½ to 2 miles long and ¼ to ½ a mile wide, the other is smaller; depth from 5 to 15 feet. They are 'raised bogs'.

26. A bog skirts the north side of Kouchibouguac harbour for 1½ miles or more; width ¼ to ½ a mile.

27. At Point Escuminac, Northumberland county, there is a large bog,—about 4 miles long and 2 wide, which is not less than 20 feet deep or more. Like other raised bogs it is nearly destitute of trees, though in many places covered with heath plants.

28. At Point Cheval on the Miramichi bay there is an interesting peat bed, much of which is dead, and composed of other plants besides mosses. Roots of trees in a good state of preservation are abundant in the bottom.

29. At the mouth of Tabusintac river, on the north side of Miramichi bay a well developed peat bog occurs, known as the 'Blacklands.' Which is upwards of 2 miles long, and a 1½ to 2 miles wide. In some places on the eastern side it is washed by the sea. It is treeless, or nearly so, raised in the centre, and has a number of small fresh water ponds occupying holes in its surface.

30. At Barreau point a peat bog of some extent occurs on the west side of a lake or lagoon; area probably two or three square miles. It is bordered by marsh.

31. A bog or 'cranberry barren' 1 or 1½ miles long, and of variable width, not exceeding half a mile in the widest part, lies at the southern end of Pokemouche harbour. Its depth is probably ten feet or more and it is composed of good clean moss.

32. On the neck of land between St. Simon inlet and Pokemouche harbour there is a fine peat bog, which covers an area of nearly 1,000 acres. Most of the peat is clean *sphagnum* and remarkably free from impurities. Like most of the larger bogs of New Brunswick the central part is raised 10 to 15 feet above the margin and is water soaked to the surface.

33. About four miles north-east of Shippegan gully, on the east side of Shippegan island, a bog 3 miles or more in length and half a mile

to a mile in width was noted. The peat was seen to be about 10 feet thick in the bank, and to be clean moss. The bottom of the bog is 8 to 10 feet above high water mark,

34. South of Pigeon hill, Shippegan island, another bog was observed between two lagoons, a mile and a half long or more and from a $\frac{1}{4}$ to $\frac{1}{2}$ a mile wide. It contains moss of good quality.

The Miscou bog.

35. The largest peat bog of New Brunswick is that of Miscou island which covers more than half of its superficies. Its greatest length is about 6 miles and its extreme width $3\frac{1}{2}$ to 4 miles. The surface of the central part is from 20 to 25 feet above sea level, and as the bottom of the peat is seen in some places to be in the littoral, it is probable that the extreme thickness is not less than from 25 to 30 feet. This central part is, as usual, the highest, the surface of the bog having a gentle slope thence to the periphery. It is, for the most part, treeless, and dotted with small ponds of icy cold water. The larger part of the bog is composed of pure *sphagnum* ; but its inaccessibility, especially in winter is against the utilization of the peat for economic purposes, there being no other way of reaching the island than by the sea.

36. On the road between Pokemouche and Caraquet, about half a mile north of Waugh river, a peat bog is crossed. It is about half a mile long and from 200 to 300 yards wide. Distance from the Caraquet railway about three miles.

37. A peat bog occurs in the middle of the peninsula terminating at point Mizzinette, in the eastern part of Gloucester county. Though treeless it is surrounded by the forest. Area and depth not ascertained. Two small lakes in it are drained into Blue cove.

38. At Bartibog station, Intercolonial railway, a peat bog of irregular form was noted. It is crossed by the railway and expands towards the east. The surface is without trees, but small black spruce and hacmatac grow on the marginal or thinner portions. It is probably a mile or more in length and fully half a mile wide; depth 5 to 10 feet.

39. Two and a half to three miles north of the same station another bog occurs of approximately the same area. These bogs contain workable peat and their proximity to railway communication enhances their value.

40. A large peat bog exists between the headwaters of Portage river, an affluent of the North-west Miramichi and Gordon brook which flows into the Nepisiguit river. It lies is about six miles west of the Intercolonial railway.

41. At the head of the north branch of Green brook, a tributary of the Bartibog river, a peat bog occurs, and another is reported to lie about two miles directly west of Beaver brook station, Intercolonial railway. Two or three miles north-east of Bartibog station, Intercolonial railway, a bog of considerable extent is said to exist, and another at the head of Little Eskedilloc, an affluent of the Tabusintac river. Two other peat bogs are reported by hunters and lumbermen to lie along the Big Eskedilloc river, one on the north, or between this river and the Little Eskedilloc, a short distance west of the old Chatham and Bathurst road, and the other on the south-east side of the largest of these rivers, three to four miles east of the post road mentioned. Moose or caribou plains in New Brunswick.

These bogs are known locally as 'moose' or 'caribou' plains, and are of great extent like many other peat bogs upon the Carboniferous area. The peat is not likely to be deep, but is, nevertheless, mostly clean *sphagnum* and of economic value.

42. At the head of the north-east branch of Portage brook, an affluent of the Nepisiquit, near the portage route between this river and Upsalquitch lake, a peat bog was observed; length about 1 mile, in a north-west and south-west direction, width from a quarter to half a mile. It seems to occupy a former lake basin and contains good living peat.

43. (1) On the south side of the Baie des Chaleurs, at Belledune, we find two peat bogs. The one nearest Belledune Point rests on a bed of marl, (2) South of Charlo river near the coast of the bay there is a small bog which is probably of economic value. The Intercolonial railway runs through a part of it.

## QUEBEC.

Peat abounds in the province of Quebec. The soil and climate seem to be peculiarly favourable to the growth and accumulation of this material, and some very large bogs are found in the valley of the St. Lawrence, and other valleys opening into it, from Matane river westward. Large bogs are also reported from the upper Ottawa and Lake Abitibi region. The quality of the mosses composing the bogs too, is excellent, the most of these being in a growing and healthy condition. Abundance of peat in the province of Quebec.

44. The largest peat area in the province is said to be on Anticosti. Here peat is reported to extend along the south side of the island for upwards of 80 miles, namely, from Heath Point to within 8 or 9 9 miles of South-west Point, with an average breadth of 2 miles. Anticosti.

Its thickness as observed on the coast is from 3 to 10 feet. Between South-west Point and the west end of the island many smaller bogs, varying in extent from 100 to 1,000 acres, occur.

Gaspé.

45. Peaty areas are of frequent occurrence on the Lower Carboniferous rocks of Bonaventure county, but they are of little depth, and most of them have not yet advanced beyond the wooded stage. One of these is crossed by the first road to the second concession north of Bonaventure river and is of considerable extent. A small one was seen on the road going back on the south side of Cullin's river. Similar small bogs were observed around the margin of the lakes behind New Carlisle and elsewhere.

46. Crossing from Baie des Chaleurs by the Intercolonial railway to the St-Lawrence Valley a peat bog was seen on the west side of Metapedia lake one or two miles north of Amqui station.

47. Between Sayabec and Moise stations another considerable extent is passed over by the railway.

St. Lawrence valley.

48. A bog in three separate belts extends from a point 2 to 3 miles east of Rimouski to Ste. Luce station and beyond, a distance of 8 to 10 miles. Width of three taken together $\frac{1}{4}$ to $\frac{1}{2}$ a mile; depth 1 to 6 feet.

49. East of Rimouski river another 3 to 4 miles long, and $\frac{3}{4}$ of a mile wide lies, which is 5 to 12 feet deep,—in one spot 30 feet.

50. At St. Eloi and Isle Verte stations I.C.R. a bog $4\frac{1}{2}$ miles long occurs on the south side of the track; width $\frac{1}{4}$ to $\frac{1}{2}$ a mile, depth 5 to 10 feet.

51. At Cacouna station there is a bog about two miles in length, and $\frac{1}{4}$ to $\frac{1}{2}$ a mile wide, 2 to 10 feet deep.

Rivière du Loup bog.

52. South of Rivière du Loup, a bog of about 6,000 acres occurs. Maximum depth 18 feet, thinning out at the edge to a foot or two. The Temiscouata railway runs along its western border.

53. Between the Intercolonial railway and the St. Lawrence river near the south-west side of the Rivière du Loup Seigniory, a bog 3 miles long extends in a north-east and south-west direction; breadth half a a mile; depth 4 to 8 feet.

54. Another occurs at L'Islet du Portage, one mile south east of Ste Helene station, I.C.R. Length north-east and south west, one to two miles, probably about $1\frac{1}{2}$ miles; width, a quarter of a mile; depth 8 to 10 feet. A third lies 6 miles S.E of St. Denis; probable length a mile, width $\frac{1}{4}$ mile, and depth about 8 feet.

55. North-east of Rivière Ouelle station, I.C.R. there is a bog of about 4000 acres; depth 3 feet at the margin to 20 or 25 feet at the centre. Attempts were made some years ago to work this bog, but except cutting some drains in a part of it nothing was done. Rivière Ouelle.

56. East of Ste. Catherine, on the Quebec and Lake St. John railway, there is a bog which is about 2 miles in diameter, and which has a depth of from 5 to 10 feet, in some spots deeper.

57. On the road between Cap. Santé and L'Enfant Jésus there is a bog with a breadth of half a mile.

58. There are several bogs west of Levis along the Grand Trunk and Intercolonial. The first is just west of Chaudière station and is about $\frac{3}{4}$ of a mile in diameter. A mile and a half east of Craig's crossing G.T.R. another occurs, $\frac{1}{2}$ a mile in diameter; and three miles west of this crossing a third was seen, 2 miles long and 1 mile wide. The depth of all these does not seem to be more than from 5 to 10 feet.

95. Of the several bogs crossed by the I.C.R., the first was noted at Rivière aux Neux, and is $\frac{3}{4}$ of a mile long and half a mile wide; depth 5 or 6 feet.

60. A bog in Lotbinière Seigniory, at Grand Rivière du Chêne, is 2 miles long and $\frac{3}{4}$ of a mile wide.

61. The Lotbiniére and Megantic railway crosses three peat bogs between Lyster and Kingsbury Jct. I.C.R. The first is 2 miles long by one wide, and shallow; depth not exceeding 5 feet. The other two are small and unimportant.

62. Peat bogs were noted on the water-shed in the vicinity of Black lake, St. Francis and Aylmer lakes, near the Quebec Central railway.

63. In Bulstrode, Arthabaska county, a bog 2 miles long and probably a mile wide occurs. Depth 5 or 6 feet. This seems to be the bog in which Mr. Hodges carried on operations in 1864-70 (see p. 30) Bulstrode bog.

64. Along the same railway three miles S.E. of St. Célestine a bog from a half to three-quarters of a mile in diameter was noted. Depth 5 to 8 feet.

65. Four miles west of Farnham, a bog nearly 4 miles long by 2 miles wide occurs. Depth not known, but the central parts are probably 10 feet. In some places it is quite shallow and has been brought under cultivation.

66. Five miles S. E. of Farnham another bog 2 miles long and 1 to $1\frac{1}{2}$ wide was noted. Depth unknown, but must be 5 feet or more;

67. South-east of Waterloo there is a bog about a mile long and half a mile or more in width. Depth from 5 to 10 feet. Mostly dead peat.

68. Near Ste. Brigitte in the county of Rouville there are peat bogs, portions of which are now under cultivation.

69. The large peat bog in the Seigniories of Lacolle and De Lery, and in the townships of Sherrington and Hemmingford, has been partly brought under cultivation. At present, a part of it, about a mile and a half long by a mile in width only, was noted at the line between the townships mentioned; depth about 10 feet.

70. South of Hemmingford there is another about a mile long by half a mile wide; depth 5 to 10 feet.

71. On the Canada Atlantic railway between Missisquoi bay and the Richelieu river a bog containing fine, living moss occurs. Area about a square mile; depth 5 to 10 feet.

St. Dominique bog.

72. At St. Dominique there is a bog which, in the sixties, was 5 or 6 miles long by 3 or 4 wide, with a maximum depth of 18 feet. Since that date a considerable area of the shallower parts has been brought under cultivation.

73. There is also a peat bog at Longueuil on the Chambly road, on which some work was done in the early sixties. Portions of this have also been brought under cultivation.

74. North of the Ottawa river, in Grenville, there are several bogs, one covers about 36 acres and is 10 feet deep; another of about the same extent is 15 feet deep; and a third of 30 acres is also said to be 15 feet deep.

75. In Harrington one bog of 40 acres is 10 to 15 feet, and another in the same township containing 60 acres is 25 feet deep in the thickest part.

76. To the east of this in Mille Isles Seigniory a bog occurs on the double range, on the road from St. Janvier to St. Jerome; length half a mile, area $\frac{5}{8}$ of a square mile; average depth 8 feet, the depth varying from 2 to 18 feet. Another bog a $\frac{1}{4}$ of a mile wide was seen near St. Janvier; and a third occurs north of the church of Ste. Anne des Plaines on the road to New Glasgow, extent about a mile, probable average depth 5 feet.

77. Near New Glasgow, Great Northern railway, a bog about 1 square mile in size occurs; depth about 5 feet.

78. In the Seigniories of St. Sulpice and L'Assomption, a bog of about 1,100 acres was noted. Depth 2 to 15 feet. Result of ten trials gave average of 10 feet.

79. In the Seigniories of Lavaltrie and Lanoraie two large bogs run parallel to each other for about 8 miles in a north-east and south-west direction; width from half a mile to 2½ miles. Area 12 to 15 square miles; depth 4 to 14 feet, average 11 feet. A third bog lies two miles from St. Laurent, length over 5 miles; width half a mile to 2 miles; area about 3 square miles; average depth 5 feet.

80. On the road along the west side of St. Maurice river (Fief St. Etienne), at Les Grès, a bog half a mile in diameter is crossed; depth about 5 feet.

81. At Garneau Jct. Grand Trunk railway, three bogs occur. The southernmost one is about ⅝ of a mile in area, and 5 feet deep. The other two are comparatively insignificant. Further north two others are seen each about ⅛ of a mile in area; depth also about 5 feet.

82. Near the Champlain river, a bog occurs; area about 1½ square miles; depth 5 feet.

List of bogs in Quebec incomplete.

The foregoing list is necessarily incomplete. A large number of bogs occur in the forest—covered part of the province, and these, besides many of the smaller have not been noted in our examination; but it includes nearly all that are accessible by railways, by roads, or water communication.

Below Quebec city all the bogs are in a green living condition, west of that many of them have been burnt over, or partly reclaimed for farming purposes. Generally speaking, the peat is thinner upon the St. Lawrence plain than where the country is undulating or hilly.

## ONTARIO.

Peat in Ontario.

Peat bogs are also very abundant in this province, and many of them are large, comprising thousands of acres. Fewer 'raised bogs' are found here than in Quebec or the maritime provinces however, much of the peat which occurs in the cleared parts of the country being dead, or having ceased to grow. In the newer and unsettled areas of western and northern Ontario the most extensive bogs in Canada are found, all in a growing and well-preserved condition.

83. In the level region of eastern Ontario between the St. Lawrence and Ottawa rivers several peat bogs occur. A considerable area of peat is reported to lie in the rear of the seigniories of Vaudreuil and Rigaud. In Caledonia, ranges 7 and 8, Alfred, the Canadian Pacific railway traverses a shallow bog for 3½ to 4 miles. Its width does not exceed 1½ to 2 miles and the depth 3 to 4 feet. A considerable part of this bog on both sides of the railway track is now being burned over and brought under cultivation.

84. In Gloucester, 3rd. 4th. and 5th. ranges and passing into Cumberland township, county of Russell, there is a large peaty tract, known as the Mer Bleue which contains approximately 5,000 acres with a maximum depth of from 25 to 30 feet, thinning out towards the margins. Towards the west it runs into three points from two of which brooks flow. The Canadian Pacific railway passes along its north side, and the Canada Atlantic on the south. The centre of the bog is only about 8 miles from Ottawa.

85. Another bog of considerable size occurs on the line between Gloucester and Osgoode townships, county of Carleton, range 4, about four miles east of the Rideau river and extends into the latter township several miles. A third smaller and apparently shallow bog is crossed by the Ottawa and Prescott railway some miles south of Chaudiere junction.

86. Three large areas of peat, from 1,000 to 3,000 acres each, occur in Nepean and Goulburn, county of Carleton; one of them to the east, and two to the west, of the village of Richmond. These have also been partially brought under cultivation.

Newington.

87. A large peat bog is situated in the county of Stormont, at Newington, 15 miles from Cornwall, and 40 from Ottawa, near the line of the Ottawa and New York railway. It contains 1,000 acres or more and ranges in depth from 17 to 30 feet. It is now being wrought by the Dominion Peat Products, Limited, of Ottawa, (see later page for description of process.)

Brockville.

88. About two miles north of Brockville, just west of the Canadian Pacific railway track, a large bog or morass, 1,400 acres in extent, occupies a basin, part of which was formerly covered by a lake. An artificial cutting has, however, drained this off, exposing a bed of mosses, remains of grasses, aquatic plants, etc. The maximum depth is 40 feet or more, the upper 3 feet being of comparatively uniform character in certain zones, while in others transported material from the slopes surrounding the basin is met with in greater or less quantity.

Below a depth of 3 feet the character of the material changes to a dark plastic mass. Quite recently a new company has acquired this property and is introducing the Sahlstrom process, a European one. (For details regarding this process see a later page).

89. At Perth, in the township of Drummond, a peat bog occurs, known locally as the 'blueberry marsh,' covering some 2,000 acres. Thirty-five acres of this were acquired by the Lanark county Peat Fuel company some years ago and an attempt made to work it for fuel, but so far without success. The average depth of the bog is about 8 or 10 feet. Very little true moss is found in the peat here, the remains of grasses, aquatic plants and weeds constituting the chief part of the bed.

90. Peat is found in the third and eighth ranges of Beckwith, to the east of Missisquoi lake; and an area of about 3,000 acres of this material occurs in Westmeath in the rear of front A, and from the first to the fifth range behind it.

91. In the ninth and tenth ranges of Huntley, county of Lanark, there are about 2,500 acres of peat, which in some parts has a thickness of 8 or 10 feet, while in other parts the bottom was not found at a depth of 15 feet.

92. A peat bog occurs on lot 12, 4th and 5th ranges of Sheffield, county of Wentworth, where it overlies a bed of marl, and extends over 300 or 400 acres. The average thickness is about 4 feet.

93. Peat bogs occur in Prince Edward county, and attempts were made to work these for fuel some time ago, but apparently without success, as nothing has been done there for some years.

94. At Galt, Waterloo county, there is a small peat bog, where work was formerly carried on.

95. The Holland river swamp in the counties of Simcoe and York, which contains approximately 20,000 acres is said to be a quaking bog and the peat, or decayed vegetable matter is, in places, upwards of 9 feet deep. At some depth below the surface it is reported to contain true peat (*Sphagnum*). Holland river swamp.

96. The Beaverton bog near the village of the same name, at Lake Simcoe occupies only about 100 acres. Like many of the other bogs of Ontario it is composed of the dead and blackened remains of woods, rushes, grasses and aquatic plants with little true *Sphagnum*. Its depth is about 40 inches, but the upper 26 inches only are available for peat fuel. Mr. Alex. Dobson, the owner of this bog devised new Beaverton bog.

methods of drying and briquetting the material which will be referred to later on.

Trent valley bog.

97. At Victoria, near the Trent Valley Canal, about two miles north of Kirkland, there is a peat bog of 110 acres; depth 10 feet or more. Another bog of 130 acres lies north of this on higher ground and is better situated than the last as regards drainage, and facilities for drying the peat in the air.

98. South-east of Victoria in the basin of Balsam lake another bog occurs having an area of about 30 acres; and south-west of the latter a third and smaller one lies. Depth of these varies from 4 to 10 feet though in one spot 55 feet.

99. A peat bog of about 25 acres occurs near Berlin, Waterloo county. It is underlaid by a deposit of shell marl. Similar small bogs are reported from other parts of the same county.

Stratford bog.

100. A bog known as 'huckleberry marsh' is situated about 8 miles north of Stratford. It contains about 2,000 acres, depth from 5 to 10 feet. Here the manufacture of peat fuel was also undertaken in 1902 with the Dobson plant, but was discontinued in 1903. The peat is nearly all dead.

Welland peat bog.

101. In Welland county near the 'feeder', of the Welland Canal there is one of the largest bogs found in the settled parts of Ontario, containing probably 5,000 acres. The average depth is from 4 to 8 feet. It is now several years since operations were begun in this bog, meantime experiments in drying and pressing the moss have passed through a number of stages. The peat here is somewhat different from that of the Beaverton and Stratford bogs. It is wetter and requires different treatment in the drying process, in order to deprive it of the moisture it contains. Owing to the great quantity of roots of trees and shrubs the peat has to be carefully screened before it is put into the breaker. This bog is nearly flat and except in the centre the peat is dead. Considerable quantities of ash must be found in it around the marginal or thinner parts.

Rondeau peat.

102. The Rondeau bog at Rondeau harbour on the shore of Lake Erie, in the county of Kent, extends along the water-front a distance of several miles with a width of a quarter to half-a-mile. Sand bars separate it from the waters of the harbour. It occupies an area of about 1,500 acres. The Western Peat Fuel Company, Limited, of Chatham, owns 328 acres of the bog, on which they have erected buildings and installed the necessary plant for manufacturing fuel. The depth of the peat is variable, ranging from 1 foot to 30 feet. Very little, if any, peat moss (*sphagnum*) is met with in the beds.

103. A bog of some extent occurs at Redmonds Pond, 2 to 3 miles below London on the north west side of the Thames river.

104. Peat bogs are reported from the valley of Nottawasaga river, near the mouth, one of these occurring at Jacks Lake.

105. Peat exists in some places on the borders of Lake St. Clair, also in parts of the district along the north side of Georgian Bay. Large tracts of peat occur along the line of the Canadian Pacific railway west of Lake Nipissing and between Port Arthur and Rat Portage.

106. In the lake Abittibi region peat bogs are common. The Great Muskeg described under the next number reaches this far east.

Great Moose river peat area.

107. Mr. E. B. Borron who explored the basin of Moose river * reports that there are in the territory belonging to Ontario, south-west of James bay, not less than 10,000 square miles overlaid with beds of peat, the depth of which is often six feet, and is, perhaps twenty feet or more in some places. The climate and natural conditions here, are most favourable to the growth of the *sphagnum* moss, and consequently immense bogs have been developed.

108. South of the Canadian Pacific railway in the Thunder Bay and Rainy River districts, and along the Canada Northern railway there are a number of peats bogs of greater or less area.

109. In the country between the Missinaibi and Albany rivers with Kenogami river to the south-west and James bay on the north-west, there are, according to Mr. W. J. Wilson, no less than 3,000 square miles of peat, probably 5 or 6 feet deep or more.

110. The same explorer informs me that on the Little Current and Drowning rivers there are probably about 1,200 square miles covered with peat varying from 2 to 5, or 6 feet in depth.

## MANITOBA.

St. Boniface bog.

111. There is a large peat bog at St. Boniface, composed, it is said, of good peat. The Peat Products Company, Limited, of Ottawa, have an option on a considerable part of it.

112. Mr. D. B. Dowling states that in the south-east corner of the province near the Canadian Pacific railway there are a number of bogs, muskegs, or flat swampy areas. The plants in these are largely aquatic forms, grasses, reeds, etc., and there is little, if any, true *sphagnum* moss.

* Report of E. B. Borron, Ont. Sess. Papers, 1887, Vol. XIII, part 4.

Julius muskeg.

113. The Julius muskeg, or peat bog, occurs partly in three townships adjacent to each other, east of Winnipeg. and in the vicinity of the Canadian Pacific railway between Whitemouth and Molson stations. It is said to contain about 100 square miles of peat.

114. East of Brokenhead river there is a peat bog or muskeg extending northward from the Canadian Pacific railway. It is about 30 miles long with an average width of three miles.

Big Grass Marsh.

115. North of Gladstone station, north-west branch of the Canadian Pacific railway, the Big Grass marsh occurs, covering about 75 square miles. This is called a peat bed though formed chiefly of grasses, sedges and aquatic plants.

NORTH-WEST TERRITORIES.

Albany river.

116. Dr. R. Bell reports that peat is found along the Albany river for 150 miles. On ascending, it is first seen about 12 miles from its mouth, and appears along its course, with some interruptions, as far up as the forks of the Kenogami. A wooded belt stretches along both sides of the Albany for a long distance and the beds of peat lie behind these.

117. In the same report Dr. Bell also states that between Martins falls on the Albany and Attawapishkat river, *sphagnum* bogs extend across the country for 60 miles.

Attawapishkat river.

118. From the mouth of Attawapishkat to Black Fence river, 135 miles, there, are according to the same authority, swamps and peat bogs, and for 30 miles below the junction of the two branches, *sphagnum* bogs occur all along. Indeed the whole country generally speaking, below Lake Landsdowne contains *sphagnum* swamps with small scattered tamarac and black spruce trees. Portions of it are however, covered more or less thickly with a larger forest growth. The peat bogs apparently stretch across north-westward to the Ekwan river. This is corroborated by what Mr. Dowling observed there. *

Kapiskau.

119. On the Kapiskau river, Mr. Wilson informs me, there are about 2,000 square miles of peat.

Ekwan.

120. Peat or muskeg occurs along the Ekwan river nearly from the mouth to about 130 miles above it, according to Mr. D. B. Dowling, and the bogs have an average width of probably 25 miles on each side. The depth is from 1 to 5 or 6 feet. On the higher parts of the

* Report of Progress, Geol. Surv. Can. 1877-78, Part CC. ; *Ibid.* 1879-80. Part C. ; Annual Report Geol. Surv. Can. Vol. II, 1886, Part G.

area the moss is often wanting and a tree growth prevails ; but most of it is covered with *sphagnum* except in the river valleys.

121. On the Winisk river Mr. Wm. McInnes says there is a bog or muskeg about 100 miles long and of unknown width, but apparently extending to the parallel rivers on both sides. Winisk.

122. Dr. Bell reports peat as occurring at or near the mouth of Nelson river 4 feet thick and running a long distance inland. He also observed it along the route from Split lake to Fort Churchill, especially at the creek north of the Hudson Bay post at Split lake ; at the outlet of Assean lake ; at the southern part of Waskaiowaka lake on both sides ; and at lagoons 12 miles south of Recluse lakes, where it is 4 feet thick on the top of the bank. Nelson river.

123. At Oxford and Knee lakes, Keewatin, Dr. Bell also reports peat, and *sphagnum* moss was noted in low places north-west of Swampy lake. Below Knee lake there is a good bed of peat of considerable extent with a perpendicular face of 4 or 5 feet above the level of the water. Peat of fine quality also occurs at Clearwater and Swampy Portage lakes. Oxford and Knee lakes.

124. Mr. A. P. Low states 'that between Favourable lake and Muskratdam lake the country is a vast level swamp, broken only by a few knobs of gneiss.... The swamp is covered with moss peat and supports a small growth of black spruce and tamarac.'

125. The *sphagnum* moss will probably be found growing northward to Churchill river and beyond it. Indeed, it would seem from the facts obtained by geologists and explorers in northern Ontario and the southern part of Keewatin territory that a great peat zone extends from the north-western part of the province of Quebec westward and northward along James and Hudson bays into Keewatin as far as the northern limit of trees, passing into Saskatchewan, Athabaska and Mackenzie. The peat in this zone seems to occur in beds of greater or less extent along rivers, around lakes, and upon the lower grounds. Between the bogs there are drier areas covered with a forest growth. Much of the peat is doubtless thin, and if burnt over, as is now being done in some parts of the St. Lawrence valley good soil might probably be found underneath. Churchill river. Peat in Saskatchewan, Athabaska and Mackenzie territories.

126. Peat is reported as occurring at a lake at the southern border of the 'barren grounds', in Mackenzie territory, by Mr. J. B. Tyrrell.

127. Dr. R. W. Ells states that along the upper waters of the North Saskatchewan river, near the eastern base of the Rocky Mountains there is a peat bog not less than 10 miles in length.

Mr. Tyrrell also speaks of 'wide marshy tracts either covered with moss or forming impassable muskegs' occurring along the upper North Saskatchewan, near the Beaver hills.

No measurement of the areas of the peat bogs west of the Great Lakes and James and Hudson bays has yet been attempted, except perhaps, in Manitoba, and even an estimate of their extent can only be the merest approximation, but it is certain that they cover many thousands of square miles, and that a large number of bogs exist which have not yet been seen by any explorer.

From the data at hand the following summary of the areas of peat in Canada, with the average depth, has been calculated. East of Lake Superior the figures are at least approximately correct; west of that they are largely estimated.

QUANTITY OF PEAT IN CANADA.

Total area and depth of peat in Canada.

| —— | Square miles. | Average depth in feet. |
|---|---|---|
| Nova Scotia and Cape Breton..... | 250 | 8 to 10 |
| Prince Edward Island..... ..... ..... | 10 | 8 " 10 |
| New Brunswick... ..... .. ..... | 250 | 8 " 10 |
| Quebec (in settled parts) .. ..... | 500 | 8 " 10 |
| Ontario ( " " )... . ..... 450<br>(Moose river Basin, etc.)..... 10,000 | 10,450 | 5 " 8 |
| Manitoba.. ..... | 500 | 6 " 10 |
| North West Territories (estimated).... . | 25,000 | 5 " 10 |
| British Columbia and Yukon Territory... | No data. | |
| | 36,970 | |
| Or in round numbers..... | 37,000 | |

The above figures are doubtless too low, as there must be a large number of peat bogs in Canada not yet observed or taken into account. Russia, it is stated, has 67,000 square miles of peat, and it is not at all improbable that this country has an area equally as large.

## ON THE MANUFACTURE OF PEAT FUEL, MOSS LITTER, ETC.

The peat beds of Canada. more especially in the eastern provinces, are now beginning to attract the attention of practical business men in view of the depletion of our forests and the increasing prices of coal, and attempts are being made to utilize them in the production of fuel, coke, and moss litter. Many of these attempts have however, only resulted in failure, after spending years of labour and considerable sums of money. This has arisen principally from the great difficulties encountered in extracting the moisture from the raw material, and in the lack of adaptation in the processes employed, to the climatic and other conditions of this country. Nevertheless, with the immense stores of peat which Canada affords, almost at our doors, it seems a foregone conclusion that the difficulties referred to should be overcome, if not by methods devised in this country, then by some of the processes in use in the different countries of Europe where circumstances have compelled the utilization of this product, and where the peat industry has been placed on a paying basis. Another difficulty and perhaps, the chief one, is the fact that our people do not care to use prepared peat in other than a condensed or pressed form, no stoves or fire-places having yet been made suitable for burning it by itself. A large portion of the experimental work in regard to converting our peat into a form for domestic or other uses has been carried out, too, without investigating the processes which have proved to be valuable in European countries. But although little success has attended the efforts of those interested, yet there seems to have been some progress made. That Canadians, should not be able to devise and carry out methods for preparing fuel from this material as well as the people of other countries seems unreasonable to suppose. The peat is practically the same as that of northern Europe, being largely sphagnaceous, and containing by analyses nearly the same constituents. The natural conditions as to climate, length of the summer season, heat and cold, drought and rainfall are not so dissimilar, and yet it is well known that in Sweden and Norway, northern Germany, Bavaria, etc., the manufacture of peat has been carried to success and very large quantities of it are used for domestic purposes, in smelting and metallurgical works, also for generating steam and in various ways. But only in three places in Canada are processes now in operation capable of producing prepared peat, namely at Beaverton, Brockville, and Newington, in the province of Ontario. Of these three processes the Beaverton plant, invented by Mr. Alex. Dobson of that place, is the only one in continuous operation. Here the peat is dried and pressed into briquettes, thus occupying much less space than

Manufacture of Peat Fuel Moss Litter, etc.

Plants operating in Canada.

the crude article. The 'Economic Process,' a German invention, has been introduced at Newington by the Dominion Peat Products Co. by which machine peat is prepared; and the 'Sahlstrom Process,' a Swedish one, now about to be employed at Brockville, are those referred to.

## THE FUEL VALUE OF PEAT.

Peat includes a number of substances of unequal fuel value, the most recently formed, spongy, light-brown kind approaching wood in composition, while the denser pitchy-brown, compact material, obtained from the lower part of the older bogs, may perhaps be compared with lignite. Unlike wood, however, it contains incombustible matter in variable quantity, from 5 to 15 per cent, or even more. Much of this, however, when the amount is large, is often due to sand mechanically intermixed. When air dried the proportion of water is from 20 to 40 per cent. When these constituents are deducted, the average composition is found to be :—

Composition of peat.

| | |
|---|---|
| Carbon | 52 to 66 per cent. |
| Hydrogen | 4·7 to 7·4 " |
| Oxygen | 28 to 39 " |
| Nitrogen | 1·5 to 3 " |

Average air-dried peat may be taken as having a calorific value of 3000-3500 units, and when freed from water by a heat of 100°C, and with a minimum of ash (4 to 5 per cent), of about 5200 units*, or from a quarter to one-third more than that of an equal weight of wood, the calorific value of absolutely dry wood being about 4,000 units.

Analyses.

Analyses of the peat mosses made from samples obtained at the undermentioned places in Canada have been found to yield the following results :—

From the St. Dominique bog, Eastern Townships of Quebec, (well dried).

| | |
|---|---|
| Fixed Carbon | 29·30 per cent. |
| Volatile matter | 63·43 " |
| Ash | 6·75 " |

* A metric unit is the amount of heat required to raise one gramme of water from 0° to 1°C.

AT THE LENNOX OR INDIAN ISLAND BOG.

*In Prince Edward Island.*

| | Mean. |
|---|---|
| Hygroscopic water | 23·76 per cent. |
| Volatile combustible matter | 41·19 " |
| Fixed Carbon | 19·83 " |
| Ash | 15·26 " |

*In Ontario.*

At the Newington bog referred to above, Stormont Co., (calculated on 15 per cent water content).

| | |
|---|---|
| Water in original sample | 87·94 per cent. |
| Volatile combustible matter | 56·74 " |
| Fixed Carbon | 27·21 " |
| Ash | 1·05 " |

At the Brockville bog,—Upper stratum, 3 feet. (Calculated on 15 per cent water content).

| | |
|---|---|
| Volatile combustible matter | 55 08 per cent. |
| Fixed Carbon | 20·62 " |
| *Ash | 9·32 " |

The lighter and more spongy varieties of peat when aired are very inflammable, firing at a temperature of about 200° C. the denser pulpy kinds ignite less readily when in the natural state and often require a still higher temperature when prepared by pulping and compression, or partial carbonization. Most kinds burn with a red smoky flame developing a strong odour which, however, has its admirers. This arises from the destructive distillation of imperfectly carbonized organic matter. The ash like that of wood is light and powdery, except when much sand is present, when it is of a denser character.

PEAT AS A FUEL COMPARED WITH WOOD AND COAL.

Value of peat as a fuel.

The value of peat as a fuel naturally depends on its calorific effect and its cost of production. To ascertain its heat value, thorough tests were made a few years ago by Prof. Klasson, one of a committee appointed by the Swedish government to investigate the value of

* The analyses of Ontario bogs are taken from a Bulletin on Peat Fuel by Mr. W. E. H. Carter, B. A. Sc. Ontario Bureau of Mines, 1903.

peat coal by the so-called Angel and Ekeland methods. The following table has been computed showing the results of these tests.* The peat coal was pronounced to be of less value than what it was claimed to be, 16 per cent of the heat used in the carbonization process of the peat being lost, and the conclusion reached was that with coal at $4 per ton or more it would be too expensive to carbonize peat, as peat coal produced in the manner described in the methods referred to would cost about $7 per ton. On the other hand it was found that, for consumers near the bogs, uncarbonized peat was the cheapest fuel that could be had in Sweden.

Tests made in Sweden.

| Composition. | Wood. | Peat. | Brown Coal. | English steam-coal. |
|---|---|---|---|---|
| | Per cent. | Per cent. | Per cent. | Per cent. |
| Carbon | 52·0 | 58.0 | 66·0 | 81·0 |
| Hydrogen | 6·2 | 5·7 | 4·6 | 5·2 |
| Oxygen | 41·7 | 35·0 | 28 0 | 1·0 |
| Sulphur | | | | 11·5 |
| Nitrogen | 0·1 | 1·2 | 1·0 | 1·3 |
| Calorics. (*a*) | 49· | 57· | 60· | 80· |
| Moisture or hydroscopicity | 20· | 22· | 25· | 7·6 |

(*a*) By calorics is here understood the amount of heat required to raise 1 kilogram of water from 0° C. to 100° C.

## CANADIAN PROCESSES FOR CONVERTING PEAT INTO FUEL, ETC.

Canadian process for making peat fuel.

Hodgess process.

1. One of the earliest attempts to manufacture peat fuel in Canada was in 1864 by Mr. James Hodges, an English engineer; and the bog in which he began operations was at Bulstrode, in Arthabaska county, Quebec. The process consisted in placing a machine with revolving disks upon a floating scow, a canal having been cut for this purpose. The scow or barge was to contain all the machinery necessary for the complete manufacture of the peat, which, when excavated was to be

*Jubilee number for 1896 of *Tiknisk, Tidscrift.* Paper by Mr. Ernest E. Sjostedt, M.E. The Mineral Industry, vol. VII, pp. 191-198.

delivered into the barge. Here it passed through machinery which removed the roots and reduced it to a soft pulp. This pulp by means of a shoot or distributor was spread out to dry upon the levelled moss by the side of the canal in a sheet 9 inches thick, and 90 feet in width. Then after two or three days it become hard, and was cut across at intervals of six inches, and subsequently divided lengthwise in the same manner at intervals of eighteen inches. As soon as these blocks of peat 18x9x6 inches were sufficiently hard for handling they were taken up and stacked for further drying. As prepared in this manner the peat held 25 per cent of water. Experiments were made with peat thus prepared, for firing locomotives on the Grand Trunk railway, but it proved too fragile for handling or transport. Fifty tons of this air-dried peat fuel could be produced in a day, costing 92 cents per ton.*

Aikman process.

2. On the suspension of operations by the Canadian Peat Fuel Company of Mr. Hodges, Mr. Aikman, who had been manager, introduced a process slightly different from that of Hodges. The peat after being pulped and freed from roots, was artificially compressed, and then dried in the air the drying requiring about six days. Mr. Aikman thus describes this process. The machinery is also carried on a scow which is made to float in the bog, the peat being extracted by a pair of large screw augers, working in front of the scow, which deposit it in a well where it is submitted to the action of steam from the exhaust of the engine. It is then carried by an elevator to the squeezer, where it is freed from about 33 per cent of water after which it is broken up by revolving teeth, passed through a centrifugal drier of a special construction and delivered into the press in the form of dry dust. By the action of heat and of the screw it is brought into a pasty condition, and the tar or resin naturally contained in the peat being softened under the pressure, it becomes partially carbonized and issues from the press in a continuous stick of peat fuel ready for use. The whole process is entirely automatic and only takes about 20 minutes from the time of excavation out of the bog till it is delivered from the press as a marketable fuel.'

The approximate cost of erecting a plant capable of producing 15 tons per day is $4,960, and the cost of operation is $16 per day.

Dickson process.

3. Another Canadian peat process of considerable interest, which was at one time thought to have overcome all difficulties, was that known as the Dickson method, invented by Mr. A. A. Dickson of Toronto. His process consisted mainly in drying the peat on the surface of the ground or in sheds, without the application of artifical

* Report of Progress, Geol. Surv. Can. 1863-66, pp. 284-291.

heat, which he considered has an injurious effect upon the peat as fuel by dissipating more or less of the contained volatile matter. The peat dried by the sun or by the air was pulverized by passing it through a breaker, and then conveyed in this condition to a large hopper whence it descended to a press and was there stamped into cylindrical briquettes 2 by 2 inches. The compression was effected in a bottomless tube, under a weight of about 30 tons, the resistance being due to the friction and to the tube narrowing slightly in the lower part. The reduction in bulk is in the proportion of 6 to 1. The briquettes are hard and dense and have stood numerous tests showing their suitability for domestic use and for producing steam. The cost was about $1.50 per ton.

The Dickson plant was introduced at several of the Ontario peat works, namely, at Brockville, Perth, Stratford and Welland, but it is not at present in use.

Dobson plant.

4. An important modification of the Dickson process has been devised and put into successful operation at Beaverton by Mr. Alex. Dobson of that place. The various stages in it may be briefly summarized as follows :—

1. Ditching and clearing the surface of the bog.
2. Track laying of tramways.
3. Digging and spreading the peat on the cleared surface as taken from the bog.
4. Raking and gathering after exposure to sun and air.
5. Loading and taking to works.
6. Drying.
7. Pressing.
8. Delivery to store-room or loading to wagons for market.

The two first are simple matters and need not be further explained ; but the third is performed at the Beaverton bog by a contrivance invented by Mr. Dobson called a "digger", driven by an electric apparatus. This machine travels up and down along the edge of a ditch 3 or 4 feet deep, the cutter being so devised that it may be raised or lowered according to the depth of peat intended to be cut. An endless chain travels down the outside and up the inside of the elevator box, and serves the double purpose of scraping off a thin portion of the peat from the plate, and of elevating it to a conveyor running across the front of the carriage. A rapidly revolving paddle wheel catches the stream of peat fragments and showers them over the surface of the bog

for a distance of 30 to 50 feet, forming a deposit of half inch or so in thickness, in excellent condition to be dried by wind and sun. It is not necessary that the first layer of peat should be dry before another is scattered upon it by the machine just described, as experience has shown that successive layers up to six inches in depth may be deposited without checking the drying process. The time required for this depends upon the weather. Wind is said to be more effective than the sun. Under favourable conditions of wind and sun, on a summer day, the moisture in a layer of peat 1 to 2 inches can be reduced from 85 per cent to 45 per cent in two or three hours. Drying the peat on the surface of the bog is not so effective however, as if it were placed upon a raised floor or platform. In a given time the latter method will take about 10 per cent more of the moisture out of the peat.

Scraping and raking the peat, in the Dobson process begin immediately after the peat is dry. This has been done by hand, and the peat taken to a tramway running from the works through the centre of the bog.

The loading of the peat thus collected into a tram-car, run by electric power, and taking it to the works is the next operation. It is generally put into a bin or stock-pile, but sometimes directly into the hopper of the "breaker" which chops or breaks it up into small particles to facilitate drying, after which it is delivered automatically to the drier.

The Dobson drier.

The Dobson drier consists of a steel tube 30 feet in length and 3 feet in diameter. This is placed inside of a rectangular brick casing, and has a pitch of 14 inches in its entire length. The space between the brick-work and the cylinder admits of free circulation of heat and gases around the outside of the latter from end to end. The fire-box is built under the higher end of the cylinder which revolves $1\frac{1}{2}$ times per minute. Angle irons 3 by 3 inches and 5 feet long are placed around the interior of the cylinder at equal distances apart, each raised by pins 3 inches from the surface. These are intended to still further break up the peat. The peat is put into the cylinder at the upper end, and passes through it by gravitation to the lower end in 20 or 30 minutes. It is then in a condition to be pressed into briquettes, and does not contain more than from 12 to 16 per cent moisture.

The dried pulverized peat as it passes from the drier empties into the buckets of an endless belt which dump it into a hopper between the drier and the briquetting press. From this it descends into the the dies where the peat in each is subjected to a pressure of about 50 tons weight. By another movement of the press the peat blocks or

briquettes are forced out below and caught up by the buckets of an endless belt and carried to a storehouse or bin. From 12 to 15 tons of pressed peat are thus prepared in a day. The cost per ton of this briquetted peat is stated to be about $1.80*.

The Dobson process has been in successful operation for four years during the summer months, and seems to have overcome the difficulties which so far have attended the preparation of peat fuel in Canada. It must be borne in mind, however, that the bog is a small dry one, and the conditions as regards the manufacture of fuel from the peat it contains are, to some extent, different from those of wet bogs.

Trent Valley Peat Works.

5. Among the unsuccessful attempts to prepare peat fuel in Canada that of the Trent Valley Peat Fuel Company may be briefly referred to. The company, it appears, had unlimited capital and intended to operate on a large scale. A very extensive plant was erected and work was carried on for two years or more, but owing to the difficulties met with in removing the water from the peat it was closed in 1902. The peat moss was submerged, and had, therefore, to be dredged. Hydraulic presses were built and used, capable of exerting, it is said, a pressure of 300 tons, or two tons to the square inch. The peat, after passing through a macerating machine, was loaded on trucks in layers between perforated trays overlaid with filter cloths and in this manner subjected to pressure. The results, so far as removing the water is concerned, may be thus stated: Average quantity of water contained in the peat as it entered the press, 77.71; on leaving the press, 63.48. This result was far too high in moisture to allow of drying afterwards by artificial heat, as air or sun drying generally reduces the contained moisture to 30 or 40 per cent. And moreover, four men and an engineer were required to operate the plant, so that the cost was too great for the quantity of peat turned out and the small amount of water extracted.

The Welland Peat Works.

6. The Welland peat bog, described on page 22, No. 101, is another of those in which a large amount of experimental work has been carried on and unfortunately with little or no practical results. It is now about 12 years since the first attempt was made to use the peat of this turbary for moss litter. The drying process has presented greater difficulties here than in most other bogs in the province, due chiefly to the fact that the bog is low, and consists to a large extent of dead peat in a wet condition. Years ago this was an undrained swamp. Some parts of the centre are still covered by growing moss; but most of it is a black mass of decaying vegetation full of roots of

* Bulletin No. 5, Ontario Bureau of Mines, prepared by W. E. Carter, B. Sc.

trees and shrubs, especially at the margin. The process of converting this peat into fuel was commenced a few years ago by a company called The Peat Industries, Limited, of Brantford. Mr. T. F. Simpson was put in charge. The artificial drying processes, especially that of the Beaverton peat works, were found ineffective owing to the denser and more saturated condition of the peat and the quantities of roots in it. Mr. Simpson, therefore, invented a drier of his own, which consisted of two parallel revolving cylinders, 30 feet long, placing one above the other, each somewhat similar to the Dobson drier, the space between them being occupied by a conveyor pan, forming, in reality, a third compartment. The peat was made first to pass through the lower cylinder, then through the intervening compartment, last through the upper cylinder, from which it was delivered to the breaker, instead of having been put into this first as in the Dobson process. The tests made of the Simpson drier, whether really complete or not, failed to reduce the moisture in the peat to less than 24 or 25 per cent, whereas, before it can be pressed into briquettes the moisture must be reduced to at least 15 per cent. This process did not, therefore, prove of value inasmuch as it was too slow in operation, as well as for the reason stated, taking between two and three hours for the peat to pass through the drier and disintegrator.

The Simpson drier.

An improved form of the Simpson drier has recently been made, but whether or not it has proved successful has not been ascertained.

7. Three years ago, The Quebec Combustible Company, Limited, of Fraserville, commenced the manufacture of peat fuel near Cacouna station, Intercolonial railway, where there is a very good bog. The process seemed to consist of pulping the peat and mixing it with crude petroleum and some other combustible materials, after which it was put into a moulding machine and formed into bricks, each brick weighing about two pounds and then dried. The capacity of the mill was 15 tons every ten hours. It was driven by a 20 horse-power engine, the boiler being heated with air-dried peat. Eight men were employed, including those who excavated the peat. The process was a mere experiment; but unfortunately in the autumn of 1901 the whole plant was destroyed by fire, and has not since been rebuilt.

Quebec Combustible Company, Cacouna.

## European Processes.

8. Two European processes are now about to be employed in the preparation of peat fuel in Ontario,—one at Newington, Stormont county, (see No. 87 list of localities of peat bogs) and the other at Brockville (No. 88 of the same list). The first is operated by the Dominion

European processes.

The "superheated air" process at Newington.

Peat Products Company, Limited, of Brantford, with head quarters in Ottawa, and the process is known as the "superheated air," or "economic" process. The plant consists of,—(1) a machine known as the German digger or cutter. A number of these are placed on the bog, each one operated by two men. Blocks of peat about a foot square are lifted by them from any depth down to 25 feet, thrown into a heap to drain off and then to be conveyed to the brick-making machine. (2) The conveyor is a trough erection with an endless chain having discs about two feet apart. Into this trough the peat is placed and the conveyer driven by a 25 horse-power engine to the power-house, where, (3) a brick machine made and largely used in Germany receives it from the end of the conveyor. The machine has screw knives which cut up the peat and press it forward to an exit or mould which shapes it into brick-form about twice the size of an ordinary building brick. These bricks run out on a board over rollers and are then placed upon strong iron trucks in tiers so that the air can get all around them. This machine will turn out 60,000 bricks per day of ten hours, and is run by the same engine as the conveyor, both taking about 14 to 16 horse-power. (4) The chambers are in groups of four, each built of brick, iron and steel, side by side with arched roofs, their dimensions being 70 x 8 x 7 feet. Into these chambers the truck loads of peat are run on rails until the whole of the chambers are filled. The furnace, or furnaces, are then put into operation, and hot air is driven into the chambers by a fan, run by a separate engine when making fuel, and by a patent blower when carbonizing or making coke. This is called the "economic process" as it consists in a mechanical and chemical combination, which enables carbonization to take place by the admixture of air and gases so as to avoid combustion. The degree of heat for fuel-making runs up to 250° and 300° F., and for carbonization 350° to 550° F., the latter taking double the time of the former. Fuel drying takes from 24 to 36 hours, and coke making, (not yet demonstrated), will take about 48 hours. The capacity of the eight chambers when the trucks are complete will be an output of 100 tons of fuel every 24 hours.

By this process the peat is not disintegrated or pulverized and then compressed, but is kept intact from the time it leaves the bog till it is put into the chambers. The bricks are reduced by drying to the size of an ordinary building brick, and quite hard. As a fuel it burns freely, in stoves, grates or furnaces, but requires close draughts. When mixed with anthracite it produces great heat. It is about twice the bulk of coal, but it is clean and gives off little odour. The

cost of production is about $1.25 per ton, if produced in large quantity ; and it can easily be sold at the factory for $3.

This "super-heating" process, as it is called, is turning out millions of tons of fuel annually in Europe. The plant introduced at Newington is the same as that of the European process. with some modifications that are said to adapt it to the working of the peat bogs of Canada.

Brockville Peat Works.

9. The second European process referred to is that now being introduce at Brockville, Ontario, and known as the Sahlstrom process, replacing the Dickson plant there at the large bog two miles north of that town, (see No. 88 for description of bog.) The Sahlstrom Fuel Syndicate installed their plant, in 1903, but owing to the lateness of the season when it was set up, postponed operations till this spring (1904). In this process the peat after being brought to the works is passed into a compressor, or squeezer as it is called, which deprives it of a large proportion of the water it contains. From this it goes into a machine which cuts or tears it into small pieces without injuring the fibre. Then it is conveyed into a specially constructed drier consisting of a number of horizontal cylinders heated by means of the waste gases drawn from the carbonizer . The peat is carried through these cylinders by screw conveyors, and during this process becomes still further broken up. The temperature in the drier is not allowed to exceed 150° C. In passing through the cylinders the remaining moisture together with wood spirit, acetic acid, etc. are distilled over and collected into condensers by the ordinary methods. On leaving the drier the peat passes into a revolving screen where the fibre is automatically removed from the crushed material. After this the peat passes into the carbonizer. Here it is partially or wholly carbonized as required, the semi-carbonized peat being more suitable for steam-raising on account of its having more flame when burning, while the fully carbonized fuel is better suited for smelting ore and for manufacturing purposes. The carbonizer is of somewhat similar construction to the drier, and is fed and wrought automatically. The inflammable gases produced in it supply all the fuel required for the entire process as well as power for driving all the machinery, and the operations being altogether automatic the costly element of labour in handling is reduced to that required for mere oversight of the operations.

The Sahlstrom process.

After leaving the carbonizer the peat passes into the cooler into which some of the distilled products, such as tar or gas are usually conducted, to be wholly or partially absorbed by the carbon. The carbon, on being cooled, passes into an ordinary briquette machine, or through a disintegrator, which latter machine converts it into a fine

powder. This has proved to be the most economical form in which coal fuels can be used as steam raisers.

By briquetting after, instead of before carbonization, it is said the Sahlstrom process not only leads to great economy of time, fuel and labour, but produces a far denser fuel, which is cleaner, suffers less loss and injury through handling and exposure to weather than any other form of peat fuel, and is even less bulky than coal, while equal to anthracite in calorific value. Unlike ordinary machine-made peat fuel, peat coal be stored in the open air, as it has very little tendency to absorb moisture.

The Sahlstrom process leads to great economy of time. From the raising of the peat from the bog until the finished fuel is ready for shipment occupies only about four hours.

Cost of prepared peat fuel by this process.

Powdered peat fuel has been used with marked success for a number of years at Jonkoping in Sweden. This kind of fuel can be manufactured at a cost of about $1.75 per ton. It is called semi-carbonized fuel, in the Sahlstrom process. Pressed peat briquettes can, however, be produced at a cost of $1.00 per ton. A third form of fuel can also be prepared, composed chiefly of pure carbon, with a calorific value equal to that of anthracite, while its bulk is rather less. This will cost about $2.50 per ton.

It is claimed for the Sahlstrom process that (1), it is an improvement on any hitherto employed, inasmuch as in the driers the peat is exposed at first to a low temperature only, which can be gradually increased until carbonization is effected; in this way the bye-products are given up separately and all practically saved. (2) These distilled products, namely, tar, ammonia, acetic acid, wood spirit, the inflammable gases, etc. etc., are collected in such a manner that they can be saved at a minimum of cost, and, (3) all the work is done automatically.

The Electric process.

7. In the February number of *Popular Mechanics* Mr. William H. Mason, United States Consul General, describes a process exhibited recently at Charlton, in Kent, England. It is known as an "electrical process" for converting ordinary peat into firm smokeless steam coal, and at a cost which promises to bring the product far within the price limit of steam fuel in Great Britain and continental Europe. The peat is cut and excavated by machinery, loaded into dumping cars which convey it from the bog to the plant, where it is packed into rotary iron cylinders of a peculiar construction. The cylinders being rotated at high velocity, the centrifugal pressure, aided by an interior

heating device, expels all but a small remnant of the water which the material originally contained. Electrodes connected by conductors with a dynamo, are then inserted in the cylinders in such a manner that the mass of centrifugally dried peat becomes the medium through which the circuit is completed between the electrodes. The resistance offered by the peat, like the filament of an incandescent lamp, generates heat which carbonizes the material, producing a mass of disintegrated black globules, which retain all the valuable elements of the original peat moss. This part of the process, which depends largely upon the conductivity of the peat, may be promoted by moistening the mass with certain cheap liquid chemicals the use of which is covered by the patent. From the cylinders the carbonized material passes to machines which knead it into a putty-like mass that is then pressed into briquettes or left to dry and harden in masses. These are broken into lumps, screened and graded like ordinary coal. Among the special advantages claimed for this method is the fact that the electrical current converts, but does not destroy, any of the valuable elements of the peat, whereas coking by fire heat expels a large percentage of these elements in the form of gases, which, being either wasted or burned as fuel beneath the retorts, are lost from the composition of the ultimate product. Briquettes produced by this method can be compactly stowed on shipboard or elsewhere; they are practically smokeless, leave no clinkers at all, and have the high thermal value of 9,000 British units. The cost of a plant capable of treating 100 tons of peat per day is stated to be $19,500. The actual cost of producing one ton of peat fuel by this process is stated to be $1.21, equal, for all steam generating purposes, to a ton of South Wales steam coal, which costs at the mouth of the mine $2.02. These are given as the economic results in a location where the electric current used by the process is generated by steam. In districts where within a working radius of peat bogs, generators can be driven by water power, the cost of production would be proportionately reduced.'

Countries in which the manufacture of peat into fuel has been a success.

8. In most of the countries of Europe in which peat occurs its manufacture into fuel has been made a success; as, for example, in Great Britain and Ireland, France, Norway and Sweden, Holland and Denmark, Germany and Russia. It seems to be in Holland that the peat fuel industry has reached the greatest development, though in Sweden and Germany it has also attained large proportions of late years. It is not only for fuel that peat is used but in the manufacture of textile fabrics also, such as mats, blankets, and certain kinds of wearing apparel, etc. In France and Russia it is made into cloth for bandages

and surgical purposes owing to its antiseptic properties, while as a fibre for paper making it is now receiving attention in England.

Acknowledgments.

In collecting the material for this bulletin the writer desires to acknowledge assistance received from Dr. R. Bell, acting director, Prof. John Macoun, assistant director and naturalist, Dr. R. W. Ells, Messrs. H. Fletcher, E. R. Faribault, Wm. McInnes, D. B. Dowling W. J. Wilson, all of the Geological Survey; his best thanks are also due to Dr. D. Spencer, President of the Dominion Peat Products, Limited, and Mr. A. J. Forward, Barrister, both of Ottawa, for valuable information. To Messrs. Alex. Dobson, Beaverton, A. F. Davis, Peterboro', T. F. Simpson, Brantford, Wilson Irwin, Toronto, and others, he is indebted for descriptions of peat bogs, processes, etc., in the province of Ontario.

URAL
ENCE
1
26
5
03
12

881

GEOLOGICAL SURVEY OF CANADA
ROBERT BELL, M.D.,D.Sc. (CANTAB.), LL.D., F.R.S.

# MINERAL RESOURCES OF CANADA

---

## BULLETIN

ON

# APATITE

(PHOSPHATE OF LIME.)

BY

R. W. ELLS, LL.D. F.R.S.C.

OTTAWA
PRINTED BY S. E. DAWSON, PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1904

No. 881

THE UNIVERSITY OF MICHIGAN LIBRARIES

Natural Science
Library
TN
226
.A3
1903
v.12

# APATITE.

By R. W. Ells.

Occurrence

Apatite or Phosphate of lime is a mineral of wide distribution, occurring in several forms and at widely separated geological horizons. In Canada, its occurrence may be described under two heads, viz., those which belong to the crytalline rocks of what is styled the Laurentian system; and those which are found in fossiliferous strata of Cambrian or Cambro-Silurian age.

Organic phosphate.

In several of the earlier reports of the Geological Survey attention was directed by Dr. T. S. Hunt to the latter class of deposits. These are found principally in the form of phosphatic nodules in certain limestones, shales and sandstones at different points in the Ottawa valley as well as at places along the lower St. Lawrence. They were held at the time to be of considerable economic importance, when properly prepared, as a valuable fertilizer for certain soils of the district. Practically no attempt has ever been made to demonstrate their utility in this respect; and in view of the great abundance of the mineral apatite in certain parts of the province of Quebec north of the Ottawa river, as well as in some portions of eastern Ontario, their commercial development will probably not be attempted.

Crystalline apatite.

Apatite as found in the crystalline rocks came markedly into prominence as a source of mineral wealth about thirty years ago. It is found in connection with certain rock masses which traverse the gneisses and limestones of the Grenville series and which have long been regarded as forming the uppermost division of the Laurentian. The mineral is of varying colours, generally a sea-green, but sometimes red, brown or greyish-white, and is generally in the massive or rock condition known as "rock phosphate" but sometimes occurs as a finely granular material when it is known as "sugar phosphate." In the process of mining, the former is more readily handled as it can be extracted in clean condition or in such form that it can be easily cobbed from the enclosing rock; while the latter is easily broken up, and though of equal value with the massive variety, is readily mixed with foreign substances, and is therefore apt to be classed as of lower grade.

Composition.

Apatite has a hardness of 4½ to 5, and in composition consists of phosphate of lime 90 to 92 per cent, with fluoride of calcium 4·6 to 7·7, and small amounts of calcium chloride and of insoluble matter. The mineral therefore both of the Quebec and Ontario districts belongs to the variety known as fluor-apatites. In the rock it is found both in a massive state in pockets of all sizes, sometimes reaching thousands of tons which are distributed in a greyish-green pyroxene; and as crystals in a matrix of calcite, either pink or white, which forms an integral portion of these intrusive masses or dykes.

The presence of apatite in the Laurentian rocks of Canada was first announced by Lieut. Ingall, in 1829, as occurring near the Lièvre river in Buckingham township; and it may be remarked that in this area some of the largest and most valuable mines of this mineral were subsequently located and worked for a number of years with great profit.

History of development.

Little attention was however attached to the discovery at that early date, and for nearly half a century its economic value was not realized. In the Geological Survey Report for 1847, Dr. Hunt referred to the presence of the mineral as occurring in the township of North Burgess in Ontario, in rocks of similar character to those in which it was found in Quebec. Mining in the district did not however commence for many years, the Burgess deposit being first opened by

Ontario.

quarrying about 1860. From this date to 1875 the annual output from the Ontario mines was scarcely more than 1,000 tons annually, the mineral being for the most part obtained from shallow surface pits, though on lot 10 range VI, two shafts were sunk to depths of 134 and 75 feet respectively.

Quebec.

In the province of Quebec phosphate mining was commenced in 1871, when a few tons were taken out near the Little Rapids on the Lièvre river apparently in Buckingham township. Development in this district was however much more rapid than in Ontario, as the value of the mineral was by this time much better known, while the deposits were much more extensive. In 1878 the output for this part of the province of Quebec amounted to 3,000 tons. Eight years later this had increased to 28,535 tons, valued at $490,331. The largest output for the province of Ontario was in 1889 when it reached the amount of 3,547 tons, valued at $38,833. This in 1894, the last year in which figures of production are given, was reduced to 1890 tons valued at $10,560, while in the province of Quebec the output subsequent to 1891 also rapidly decreased and in 1895 the exports amounted to only 250 tons valued at $2,500. The chief causes which led to this

decline in such an important mining industry was the exploitation of the cheaply mined phosphates of the southern states of Carolina, Georgia, &c. At the close of the industry in Ontario and Quebec the amount of the mineral in sight at the principal mining centres had shown no appreciable diminution.

Associated rocks.

The country rocks of the apatite bearing areas, both in Quebec and eastern Ontario, are practically the same. They consist of gneiss of various colours, sometimes garnetiferous, red, grey and black, with which are associated beds of white quartzite and crystalline limestone, the latter forming the highest member of the Grenville series in Quebec. These rocks are intersected by numerous veins and dykes, sometimes reaching masses of large dimensions, comprising diabase, pyroxene and granite, the latter including pegmatites in the form of dykes sometimes of considerable size. The pegmatite is more recent than the pyroxene since it cuts the latter in all directions, and this in turn is intersected by the diabase dykes. These features of intrusion are seen at most of the mines throughout the Lièvre or Buckingham district as well as in the township of Templeton and Hull nearer the Gatineau. Similar occurrences are always found in the apatite districts of Ontario.

Areas north of the Ottawa.

While the area of the Grenville series of rocks is of great extent the portion which carries workable deposits of apatite is comparatively limited. Thus in the province of Quebec the mines are practically confined to a belt in the vicinity of the Lièvre, in the townships of Buckingham and in Portland east and west, and further west in Templeton. Of these the most extensive and valuable are found in a well defined zone which extends nearly parallel to the Lièvre, beginning a short distance north of what is known as Chalifoux landing on the west side of the river and continuing with some interruptions to the vicinity of the High falls, a distance of about five miles. On this range some of the largest mining areas are found, including the Ross Mountain and Crown Hill, the High Rock, Star Hill, Central Lake and High Falls deposits. On the east side also a number of large mines are located beginning with the Etna, Squaw hill and the Emerald on the south, which are situated about nine miles north of Buckingham village, and extending northward for about eight miles, including in the northern part such important mining centres as Little Rapids, the North Star, and others in the area between the Lièvre and Tamo lake. In this belt the occurrences of the pyroxene are well-defined but the masses in the aggregate are not so large or so continuous as in the hill on the west side of the river.

Mode of occurrence.

In many of the mines of this district, more especially in the group west of the Lièvre, the apatite is found in the massive form in pockets and irregular veins which occur in the mass of the pyroxene itself. These pockets have been described by several writers as forming true beds, but a close examination over a large series failed to show this feature. In some of the occurrences the quantity of the apatite was very large, exhibiting a chimney like structure, and where several of those were found, occurring along a fairly well defined course, the series were often connected by small stringers of the mineral, though this was by no means a universal feature. Many of these occurrences

In pyroxene.

were found to be shallow isolated deposits with no indication of bedded or vein structure, and in the early days of mining much of the work was, to a large extent, confined to extracting the apatite from these surface shows, since such mining required but a small amount of capital, and when one was exhausted another could be readily found. In some of the larger mines however a system of deep mining was instituted, and before the close of the industry in 1892-93 several of the shafts and workings were carried to a depth of several hundred feet, following downward along a system of irregular veins and pockety masses which continued to the lowest depths reached.

As calcite.

In several of the mines on the east side of the Lièvre and in the Templeton and Gatineau districts as well, the conditions of occurrence appear to be somewhat different. Here the pyroxene as a rule occurs more in the form of dykes, some of which are of large size, but in these, near the contact with the surrounding gneiss, masses of pink calcite, which form an integral portion of the intrusive rocks, are seen, in which the apatite occurs in the form of crystals, associated with mica and crystals of pyroxene as well as other minerals. Some of the apatite crystals thus found are of large dimensions, reaching a weight of some hundreds of pounds, but in many the terminal angles are rounded off. The proportion of apatite contained in the calcite matrix is however usually too small to render the working of such deposits profitable. This mode of occurrence is common in the mines of the Burgess and Kingston districts in Ontario. At the present time in the process of mica mining on such deposits a large amount of this crystalline apatite is now taken out and saved as a by-product. Such occurrences are classed as veins, the foot wall being the pyroxene rock while the hanging wall is formed by the gneiss through which the original pyroxene intrusion has cut.

Calcite replaced by apatite.

In some of the mines of the Templeton district, midway between the Lièvre and Gatineau rivers, as at the Blackburn and at Battle

lake the association of the mica and apatite with the calcite is frequent. In these cases the calcite is sometimes almost entirely replaced by the apatite, and the mica, which elsewhere is found in the former as a vein filling, occurs in large masses in the latter. Similar interchanges of apatite and calcite as vein matter are observed in several of the Ontario mines as in the Sydenham district. This close association of the mica and apatite has been referred to in the Bulletin on Mica recently published.

Apatite confined to Ontario and Quebec.

In the eastern provinces of Nova Scotia and New Brunswick and in that part of Quebec, east of the St. Lawrence river, no rocks carrying this variety of apatite have been found. While in the two provinces first named there are quite large areas of the crystalline gneiss and limestones which are regarded as the equivalents, in part at least, of the Grenville series of Quebec and Ontario, similar conditions as regards the occurrence of the apatite do not appear to have prevailed. In the rocks of the western mountain region also, along the Pacific coast and throughout the Rocky mountain range in so far as these have been examined, this mineral has not yet been reported, although deposits of mica are known to occur at several points. These are however related to the granitic intrusions of that area.

Its association with pyroxene.

Origin.

The crystalline apatite of the old rocks of Quebec and Ontario is always found in connection with pyroxene, which is clearly intrusive through the gneiss and crystalline limestone, and of more recent date. The old theory, maintained for many years, that these pyroxenes represented altered sediments, laid down as an integral portion of the associated gneissic and other related strata, has long since been abandoned by those who have most closely studied the field relations of the several rock groups. It is also probable, that in many cases the presence of the apatite in quantity, even in the pyroxene, is in many cases due to the action of other dykes of granite and diabase which frequently are seen traversing the former, and in close association with which some of the largest deposits have been opened. The assertion has been made by some that apatite sometimes occurs with the ordinary gneiss as well as in the pyroxene, but of this we have no evidence in so far as the Canadian deposits are concerned, where in every observed case it has been clearly established that the mineral occurs exclusively, as regards the workable mines, in connection with the intrusive pyroxene, and even in such cases as occurrences in calcite this vein matter has no relation whatever to the altered limestone, quartzite or gneiss of the Laurentian rocks.

Origin.

The question of the origin of apatite was for some years an important one and led to much discussion. By several leading authorities, including Sir William Dawson, Dr. T. S. Hunt and others it was strongly maintained that it was of a purely organic nature, resulting from the decomposition and alteration of the earlier forms of life which were supposed to be abundant in that early time. In support of this view the supposed fossil form known as Eozoon was cited, as well as the widely disseminated occurrence of graphite in the older crystallines and of many of the iron ores, all of which were supposed by these authorities to owe their presence to organic agencies. On the other hand some persons maintained that from the mode of its occurrence in igneous rocks its presence and origin were due to causes not quite clear, but certainly not organic and probably arose from the action of phosphoric acids upon certain portions of the pyroxene, which they maintained was of igneous origin rather than an altered sediment, or to ascending vapours which were brought to the surface with the advent of the eruptive rocks with which the mineral was associated. Among the supporters of this theory in Canada may be mentioned Dr. Robert Bell, Dr. Selwyn, Mr. Eugene Coste and others. This view was also maintained by the Norwegian geologists as accounting best for the origin of the Norway phosphates which there occur in almost identical rocks and under similar conditions to those found in Canada. The discussion of the several views of the different authorities on this point will be found in "Mineral Resources of Quebec," published in the Report of the Geological Survey, 1888-89, and need not here be repeated.

Organic as opposed to igneous.

Dr. Hunt's views quoted.

In the Geology of Canada, 1863, Dr. Hunt, in describing the presence of apatite in the rocks of North Elmsley and Burgess, in Ontario, says that "the mineral is found in beds of limestone in the form of grains and crystals", but subsequently in 1866, states that it also occurs in veins. In regard to its presence in the limestones he makes the statement, on page 188, in describing the so called vein structure, that "I have described localities of crystallized apatite as occurring in beds of limestone in Burgess, where a subsequent examination, (while confirming the existence of the mineral in the limestone beds of that region) has shown nevertheless that the workable deposits are, with few, if any, exceptions confined to the veinstones. From a lithological point of view, there cannot be any objection to extending the name of limestone to these calcareous veinstones, but geologically, it becomes important to discriminate between them and those great masses of limestone which are sedimentary deposits". It will thus be seen that Dr. Hunt at that date recognized clearly the true distinction

between the calcite associated with the pyroxene and the limestone of the gneiss formation.

In this connection, Mr. J. Fraser Torrance, M.E. in the Report for 1882-83, in speaking of the presence of the apatite in the area west of the Lièvre river, regards the mineral as occurring as irregular segregations in the country rock, and as confined to one or more zones which follow approximately the course of the Lièvre, in a generally north-west direction. He states that the rock is more or less impregnated with the mineral; and from a close study of the several mines throughout the district over a large area, concludes that the statement of Hunt in regard to the nature of these deposits, viz., that they are divisible into two classes, as bed and fissure veins, is correct if we use the term bed in a sufficiently broad sense, but the majority of the deposits are very irregular segregations from the phosphate bearing country rock, which is generally a massive pyroxenite. As deposits are found in a certain bed which is more or less richly impregnated with phosphate and may sometimes be traced for a considerable distance, such deposits may be said to be merely a bed of phosphate of irregular richness. Exception is taken to this kind of classification as misleading, since it seems to imply the submarine origin of these deposits; whereas the origin of these pyroxenic rocks may possibly be due to contemporaneous intrusion. M. J. Fraser Tarrance.

Later, in the Report for 1887-88, Mr. Eugene Coste, in discussing the origin of the iron ores and apatites of the Ontario and Quebec districts, accentuates this intrusive character much more strongly. He declared strongly for the eruptive nature of the apatite bearing rocks in Canada, and held that the apatite occurs as the result of emanations which have accompanied or immediately followed the intrusion through the country rock of the several districts of many kinds of igneous rocks which are no doubt the equivalents of the volcanic rocks of to-day. He holds that these mineral deposits as well as the intrusives are deep seated in their origin, and that the fears often entertained by miners of phosphate, that their deposits are mere surface pockets, are not well founded. He says "if this origin is understood it will facilitate and encourage the working of these deposits in depth, because the accompanying igneous rock, forming a mass or dyke alongside the deposit, will be easy to follow, and because if it is apatite or iron bearing at the surface, it will always be a guarantee that it will also be in depth, as each separate mass of igneous rock is generally constant in composition". It may be here remarked that this contention of Mr. Coste's has been borne out in several of the deep mines of the Templeton and Buckingham districts. Mr. Eugène Coste.

Later, in the Report for 1890-91, after a careful examination of the apatite areas, Mr. E. D. Ingall came to the conclusion that the pyroxenite which carries the apatite and is associated with gneiss, granite, &c., is apparently intrusive in the gneissoid rocks, and all the phosphate deposits of importance occur in it.

Mr. E. D. Ingall.

He further says that "the phosphate bodies are distributed through these belts in the most irregular manner, each one varying from the other in the details of its characteristics, showing in common, however the features of extreme irregularity. In a few instances they show a general extension of the phosphate in a plane which gives the openings made on them the appearance of having followed a vein, but there are no walls or sharp planes of division which persist for any distance between the phosphate and enclosing rock. Most of the excavations made, show the bodies of mineral to have been of extremely irregular shape; merging into the enclosing rock and holding a very varying proportion of intermixed rock. At places very large bodies of almost pure phosphate have been encountered, yielding many thousand tons".

Prof. A. Osann.

Of still later date is the report by Prof. A. Osann of Germany, who in 1899, made a somewhat exhaustive study of the occurrences of apatite, mica and graphite in the district north of Ottawa. In his report for the year 1899, Vol. XII, he clearly shows that the large pyroxene masses of the Lièvre district are intrusive in their nature, see pp. 17-27. That where the smaller pyroxene processes penetrate the country rock they sometimes assume the form of veins, but that all the occurrences of rock and mineral are of later date than the rocks which they penetrate, and by inference that the contained apatite, while sometimes occurring in vein form as in the Gatineau district, and in some of the Templeton mines, and as pockets of large extent as on the Lièvre, is not of organic origin; and from the weight of evidence collected during the last fifteen years it may safely be asserted that the view once maintained as to the sedimentary nature of the apatite bearing pyroxenes has been very clearly disproved, not only from their study in the field but by their examination under the microscope, and that it is now generally admitted that they belong to the class of igneous and intrusive rocks.

Mode of occurrence.

The determination of the mode of occurrence and origin of the apatite deposits is of great importance as regards the probable profitable development of the mines at different centres. Thus as regards the presence of the mineral in the crystalline form it is clearly shown that it is found not in beds of limestone proper but in calcite masses

in the pyroxene which have been loosely called limestone by many mining experts. So also as regards its presence, as sometimes stated, in the gneiss where the pyroxene is found in small quantities disseminated through portions of the ordinary greyish variety, no apatite has ever been found unless as mere indications. As regards the occurrence of the limestones themselves, while now universally considered as a portion of the altered sedimentary rocks of the Grenville series, various other opinions have been held from time to time by eminent authorities, some maintaining that all the calcareous bodies are of similar origin and aqueous in their nature, while others, many years ago, including Emmons, Mather, &c., came to the conclusion that the crystalline limestones themselves were to be accounted for as really igneous rocks.

Whether these deposits are found as beds or veins has long formed a subject for discussion by many writers. The investigations made in 1892-93 by the writer led to certain conclusions which may here be briefly stated.

Formerly many of the apatite bearing dykes of pyroxene were regarded as true veins though their occurrence as traversing the crystalline rocks, gneiss or limestone was clearly pointed out; so that it became the custom for some years, in describing the presence of the mineral, to assign its position as occurring either in the form of true veins or beds only. Of the former kind its presence in small dykes of pyroxene where it is always found in or near the edge of contact with the enclosing gneiss, was so regarded, as also the cases where it is found in connection with calcite which formed the outer portion of these pyroxene masses in many places. Where the mineral occurred in connection with the larger masses of the pyroxene sometimes in deposits of great extent following along irregular lines, such occurrence was held to pertain to the bed type, on the supposition that all the containing rocks were true bedded strata and formed an integral part of the gneiss and limestone formation.

Igneous nature of pyroxenite.

From the manner in which the pyroxene occurs when in large areas, as is often the case in the mines along the Lièvre river, this theory as to its bedded character does not hold, as has already been indicated from the statements of others already quoted. In many places the associated rocks are displaced to a considerable extent; in other cases the mass of the pyroxene, as seen at a number of openings, has not reached the surface but appears to have pushed up the overlying gneiss or quartzite, forming a dome-shaped structure of clearly intrusive matter in which the apatite occurs.

As to the vein character of the smaller dykes which are often clearly side spurs from the larger masses, following rents made in the overlying strata, traversing these in all directions, and clearly connected with these larger intrusive bodies, it is not yet sufficiently evident why these should be classed as veins instead of spur dykes.

Vein character of deposits.

As for the vein-like nature of the many deposits which occur with calcite, and which hold crystals of apatite, mica, pyroxene and other minerals, it may be said that these present many of the features of true veins, and have been so regarded by Osann and by other recent observers of the district, and the several minerals apparently owe their presence to segregation agencies. The calcite is evidently the matrix or filling in which the crystals are embedded, but in a number of cases this calcite gives place to apatite through which the mica and pyroxene crystals are scattered. In this case however there are no well defined foot or hanging walls, the latter being a sharp contact with gneiss, while the former is formed by the body of the pyroxene itself through which for a short distance the crystals of the several minerals are disseminated. This feature is also found in connection with other mineral occurrences, such as the actinolite deposits of Elzevir township in Ontario, where along faulted contacts between the diorites which sometimes hold the mineral, and the underlying hornblende rocks, asbestiform crystals are disseminated in the foot wall to a depth of several inches.

Association of apatite and mica.

In Canada the apatite is usually closely associated with mica, and in the early days of the mining industry the mica was removed and went to the dump as a practically waste product, many hundreds of tons in this way being lost to commerce. This was to some extent due at that time to lack of market and to the consequent small value attached to the mica. At the present time many of these old phosphate mines have been converted into mica mines, and the former is now saved as a by-product, and being extracted at a small cost is claimed to be sold at a profit even at the present low prices obtainable. At a number of the mica mines, however, no apatite occurs, or at least in such small quantities as to be of but small economic importance.

Pockety character.

In actual mining it was frequently found that the apatite was of but small economic value when it occurred in the vein form with calcite and mica, since the amount of the mineral present, even in the crystalline form, was insufficient to repay the actual cost of its extraction by itself. The great economic deposits of the mineral are those in which the apatite is found in large pockety masses, often without much mica being present. In such cases the extraction when properly

conducted was made at a comparatively small cost and at the prices which prevailed some twenty years ago produced a large margin of profit. Such deposits sometimes continued downward to a great distance and even at a depth of over 600 feet, as at the North Star mine, there appeared to but little change as to production.

Deep mining.

In the case of these deep mines it is practically impossible to say where such deposits would terminate since the conditions which have affected its occurrence in the upper workings are similar throughout, the apatite being found along the margins of the intrusive dyke, in which it appears to have been deposited through the action of acids which have ascended along the course of the dyke and have impregnated the pyroxene along the zone of contact. The presence of the mineral in such cases is often similar along both margins of the intrusion.

Mr. Burley Smith quoted.

In some, in fact in the majority of the mines examined in the Lièvre district, the presence of the mineral seems to be assocaited with later intrusions of diabase which traverse the pyroxene. One of the best illustrations of this peculiarity is seen at the old Etna mine workings where a shaft was sunk along the south side of one of these diabase dykes to a depth of nearly 200 feet in a mass of apatite which was followed down with the diabase as a foot wall. In places large deposits of pyrite were found in the base of the apatite, and the action of the newer intrusion was evidenced at many points by the alteration of the adjacent rocks. In connection with this feature Mr. Burley Smith, the manager of these mines, remarks that " whatever may have been the origin of the apatite and how it came there, there is no question that the ore is found only in and accompanying the pyroxene, which according to the best authorities are immense dykes intruding through the stratified gneiss to the surface, not always however coming quite to the surface but sometimes covered with a cap-rock. Experience shows that it is useless to look for apatite away from these conditions."

" The deposits having the appearance and many marked characters of pockety veins cannot be called true fissure veins, but having these characteristics they can and should be sought and mined for on a system applicable to vein mining. They have often walls corresponding to the foot and hanging walls of true fissure veins. Their direction is not uniform but generally N.E. and S.W., varying some degrees, but a group of these deposits appear to always run parallel to the same axis, having also the same inclination, and though the so-called veins may alternate from wide bunches to tiny strings they never quite give out and may sometime be traced for a very long distance."

"Again they are traversed by dykes of evidently much more recent intrusion than the pyroxene dykes, cutting right up through them to the surface where they present the appearance of hogs-backs. At these points the vein-like deposits are thrown to one side or the other forming as it were cross courses, often widening out at the junction into considerable pockets. Perhaps the strongest feature is that the so-called vein will often continue to follow the face of the cross dyke for a considerable distance laterally and frequently right up to the surface. I am quite unable to account for this unless it has been by the refusion caused by the igneous effect of the last intrusion, the great number of apatite and pyroxene crystals near the surface strongly favouring this view, together with the burnt appearance of the rocks at the surface." Can. Mining Review, March, 1893, p. 43.

A somewhat close study was made by the writer in 1892-93 of all the known occurrences of apatite of commercial importance, north of the Ottawa; and from this certain facts then observed may be stated. Outside of the area in Quebec, enclosed by the Gatineau and Lièvre rivers, and the deposits in Portland east, no deposits of economic importance were observed beyond a distance of twenty-five to thirty miles north of the Ottawa.

East of the Lièvre river the principal mining areas are found as follows:—

Areas east of Lièvre river.

TOWNSHIP OF BUCKINGHAM.

Range XII, lots 17 and 18, the Squaw Hill and Aetna.

" XII, lot 19, the Emerald.

" XI, lot 19, the Washington or Lansdowne mine.

IN THE TOWNSHIP OF PORTLAND EAST.

Range I, lot 6, the Little Rapids mine, (formerly Watts)

" II, lot 3, the Fowler and Bacon mines.

" II, lot, 8, the London mine, nearest the Lièvre.

" II, lots 2 and 13, owned by the Compagnie Française des Phosphates du Canada.

" II, lot 7, the London mine.

" III, lots 1 and 2, owned by the French Co.

" IV, S. ½ lot 1, west ½ lot 2, French Co.

Range IV, E. ½ lot 2, the Glasgow mine.

" V, E. ½ lot 9, French Co.

" V, lot 13, the Mallette mine,

" V, lot 7, The Tamo Lake mine.

" VI, lots 7, 8, 9, 10, The French Co.

" VI, " 16, 17, 18, Chapleau's, the mine on 18.

" VI, " 2, River front, The Salette mine.

" VII, lots 7, 8, 9, 10, The French Co.

" VII, lot 16, 17, The Sweetland mine.

" VII, " 18, The North Star mine. (Haycocks).

" VII, " 24, The Croft mine.

" VIII, lots 9, 10, 11, 12, 16, 17, The French Co.

" VIII, " 26, The Philadelphia mine.

" VIII, " 27, The McLaren mine. (Camerons).

" IX, lots 9, S ½ 16, 17, 18, 19, 20, The French Co.

In this group are some very important mines, including the Little Rapids, the Emerald, Squaw Hill, and Aetna, the North Star the French Co's mine on range II, and the London mine.

## PORTLAND WEST.

In the township of Portland west on the west side of the Lièvre are located some of the largest and most productive mines of the district, among which may be mentioned the following :—The areas being taken from the manuscript map of the district prepared by Mr. E. D. Ingall and Mr. James White. Areas west of Lièvre river.

Ross Mountain mines, lots 5, 6, range VI ; 1, 2, VII, River front.

Crown Hill mines, lots 3, 4, range VII, River front.

High Rock mines, lots 5, 6, range VII, River front ; lots 7, 8 range VII ; and lots 1, 2, range VIII.

Canada Phosphate Co., Star Hill mine, lots 3, 4, range VIII, River front, lots 7, 8, 9, same range, lots 7, 8, range IX.

Chapleau mine, lot 5, range VIII, River front.

Dugway mine, lot 9, range VIII.

Central Lake mines, lots 7, 8, 9, 10, range X.

TOWNSHIP OF BOWMAN.

High Falls mines, lots 1, 2, 3, 4, range IV.

As the conditions regarding the occurrence of the apatite can be well studied at this group of mines and were carefully investigated during their development, a short statement of certain points then observed may be of interest as viewed from the geological standpoint, and as illustrating some of the views already briefly stated as to the actual occurrence of the apatite, and its relation to the containing rock masses.

The country rock throughout consists of greyish, sometimes reddish gneiss with quartzite, and occasionally thin bands of crystalline limestone. The generally regular strike of these rocks throughout the area has been frequently disturbed through the agency of the intrusive masses of gabbro or pyroxenic diorite which is sometimes seen in large masses, in places with a capping of the gneiss, such contacts being well exposed in several of the large pits.

### CROWN HILL.

Crown Hill mine.

At the Crown Hill, the gneiss and quartzite are in places quite rusty from the presence of quantities of pyrite which have been developed along or near the contact of the pyroxene or of the pegmatite dykes. The quartz of the latter, which with a generally white felspar makes up the mass of the dyke, is often of a peculiar lilac blue tint. The apatite is found in the pyroxene, which does not follow the lines of stratification of the gneiss, either as small irregular pockets near the hard granite, or in some cases along jointing planes. Some of the intrusive rock has the aspect of anorthosite without gneissic structure.

In a couple of pits which are situated about midway up the slope of the hill on the south-east side in a mass of pyroxenic diorite, which has burst through and displaced the gneiss in contact, there is a cross dyke of diabase and the apatite is found near the contact of this with the pyroxene rock.

In a third pit near the crest of the hill a well defined vein-like occurrence of apatite is presented in the pyroxene with a course of N. 25° E. It cuts across hornblende gneiss and is associated with a green pyroxenic diorite or gabbro, and in the upper part with a two foot dyke of the peculiar diorite known as concretionary or "Leopard rock". This weathers a dirty white and shows well the concretionary structure

on the weathered surfaces. The apatite sends off small spur-like veins from the sides of the main deposit which has a thickness in places of 12 to 14 inches. Near the crest of the hill the apatite-bearing band is apparently cut out between the diorite and the "Leopard rock". The quartzite and banded gneiss in the vicinity has a strike of N. 75° W. vertical.

### ROSS MOUNTAIN MINE.

At the summit of the hill at the Ross Mountain mine, the plant of which was removed some years ago, a deep pit was sunk in a rock composed of felspar and the bluish quartz, which cut the pyroxene, and from along the contact a large amount of pockety apatite was extracted. Here a small mass of calcite occurred in the pyroxene in which were masses of crystals of apatite and pyroxene but there are no beds of true limestone nor any stratification visible in these rocks. About 75 yards south of the old engine house the rocks are regularly banded gneiss and quartzite free of diorite intrusions and showing no trace of apatite. Ross Mountain mine.

In a second pit of the Ross mine east of the engine house, sunk in a hard dark-grey pyroxene which presents the aspect of a true intrusive mass and is well jointed in places, the apatite occurred in a series of pockets which yielded a large amount of the mineral. Just west of the pit the gneiss and quartzite strikes N. 15° E., with a high dip to the south, and this is cut by small diorite dykes which follow the planes of stratification.

One hundred and fifty yards north of this the apatite occurred in chimney form in a hard greenish pyroxene which carried the mineral in detached pockets without any indication of bedded or vein structure. Similar pockety occurrences were seen on the north-west side of the hill towards High Rock in an opening about 100 feet long. Here the gneiss strikes N. 60° W. vertical, the dip of the pyroxene dyke is S. W. $<70°$.

At the west pit of the Crown Hill mine near the end of the old track, a large pit was sunk in a mass of pyroxene which was cut by pegmatite. The pyroxene cuts across the gneiss which strikes N. 60° W. vertical, while the course of the dyke is N. and S. with a dip to the east of 60 degrees. The pyroxene is a hard dirty-green dioritic looking rock. Crossing the ridge to the old track the gneiss is rusty and is cut by pyroxene and pegmatite and in the former are the usual pockety occurrences. The gneiss, which has a N W. strike, is pushed

off to the south-west as if by the intrusive mass, and the apatite impregnates the pyroxene to a distance of 8 to 10 feet from the line of contact. The occurrences of apatite in detached pockets are frequent at a number of pits in this area and the gneiss is frequently very rusty from the pyrites which accompanies the contact. The presence of the apatite is often first indicated by small patches of the mineral which sometimes swell out into large masses yielding many hundreds of tons, but sometimes these are cut off abruptly as if by faults.

Near the summit of the hill at this mine, two pits were carefully examined. The gneiss strikes N. 70° W. with a south-west dip, and at the pits is cut off abruptly by a dyke of white pegmatite which intersects a mass of dark pyroxenic diorite. Both these are cut by a three foot dyke of fine-grained blackish diabase, of evidently later date, and the apatite occurs here in the form of chimney-like pockets connected by a small vein of the mineral. In the dumps small patches of the apatite are seen attached both to the pyroxene and to the pegmatite, but is rarely seen in the gneiss, so that the apatite would appear to have followed the intrusion of the granite through the pyroxene.

On a road leading up from Crown Hill to High Rock, the gneiss and quartzite are well banded with a strike of N. 40° W. and a south-west dip of 75 degrees. They are cut off squarely across the strike by a dyke of white pegmatite holding purple quartz, and a fourth of a mile south-east of the engine house the dip is reversed to N. 65° E. indicating an anticlinal along which the contorted character of the beds is admirably seen. On the road west, and at the Dugway mine, the same occurrences of gneiss, pyroxene and pegmatite are visible; and at the mine itself the gneiss is locally deflected where the pyroxene is largely developed.

### STAR HILL MINE.

Star Hill mine.

At this mine the main pit is sunk in a heavy dyke of green pyroxenic diorite, cut by white and red granite dykes. There is no gneiss visible at the pit itself and the apatite occurs as a vein or fissure deposit near the granite contact. A short distance north of the pit the gneiss and quartzite are very rusty, and where the diorite crosses, is much twisted and broken, with spurs leading off from the main dyke. Much of the gneiss is garnetiferous and is cut across the strike by the pyroxene mass and by the pegmatite.

A second pit shows the run of the pockety masses of apatite to follow closely along the strike of the gneiss, the pyroxene coming to

the surface along the lines of banding, and the apatite is near the contact in the pyroxene. Similar occurrences are seen in the more northerly pits where also the pyroxene is cut across by the pegmatite. It would seem from so many illustrations of this mode of occurrence of the apatite, near the intersecting granite, that the presence of the mineral is to a large extent due to the agency of the later intrusion.

### HIGH ROCK MINE.

High rock mine.

This mine is situated on the crest of a hill, about 600 feet above the river and was connected with the landing stage by a tramway, nearly two miles long built down the eastern slope. The country rock is for the most part the ordinary rusty gneiss and quartzite, with a general strike of N. 65° W. and a south-west dip. At the crest of the hill, the pyroxene has a very large development, through which pegmatite intrusions are numerous and sometimes of large size. The apatite has been developed, not only along the crest of the ridge but is also found in large pockety masses well down the side, being opened as far down as 400 feet from the top, where it is well exposed in a series of pits and trenches, especially along the south-west side of the hill. Here it is found along the south side of a heavy dyke of dolorite which forms a foot wall for the deposits, so that the apatite appears to owe its presence to this later intrusion. The apatite occurs in immense pockets and of fine quality. Similar occurrences are noted at a number of the pits on the crest of the hill and along the west slope, where sometimes the pyroxene mass shows a capping of the gneiss which appears to have been thrust upward by the intrusive agency.

In fact it would appear that in the area between Chalifoux's landing to the south-east of Ross mountain as far north as the High Falls mine, a distance of some five miles, there is a remarkable development of the pyroxene which, while not continuous throughout, shows its presence in large masses at many points.

### CENTRAL LAKE MINE.

Central Lake mine.

The next mine going north is known as the Central Lake area. Here also the ordinary country rock is gneiss and quartzite, with which occur bands of crystalline limestone, which show a short distance to the east of the workings. The strike of the rocks here is about north and south and the dip west 75 degrees. The pyroxene at the several pits carries mica as well as apatite, and at one of the pits the pyroxene is cut by a white pegmatite dyke which in turn is cut by a heavy dyke

of dark gray diabase. In several of the pits the mica and apatite are closely associated along the contact of one of the dykes, and these occur with local thickenings which have been excavated in chimney form to a considerable depth. These pockets thin out at the sides and show small stringers as side spurs or dykes, on either side of the excavations.

A third pit at this place is sunk in a heavy mass of greyish pyroxene which cuts a rusty hornblendic and quartzose gneiss, the edges of which have been bent upward along the side of the dyke for several feet, the apatite occurring close to the contact in the form of chimney-like pockets, with thin bands of pyroxene at each side along the contact zone. It would seem in such cases that the apatite owes its presence to deep-seated agencies.

### HIGH FALLS MINE.

High Falls mine.

The most northerly of the mines of the group is known as the High Falls. The country rock is the usual rusty gneiss and quartzite with a considerable development of crystalline limestone to the east in the direction of the Lièvre river. The usual presence of the pyroxene in large masses is here seen with intersections of the pegmatite as at the other mines already described. At the mine itself, which is on the east side of the ridge about a mile west of the river, the rock is a dark pyroxenic diorite like that at High Rock, and the apatite occurs in detached chimney-like pockets. At the most northerly pit the gneiss strikes N. 40° E. and dips S.E. $<70°$. The apatite at this place does not follow the run of the gneiss, but in this and in other pits to the south west the excavations have a course of N. 25° W., the roof sloping to the west at an angle of 15 degrees. Towards a lake known as Bowman's, there is an intrusive mass of purple grey colour resembling anorthosite which cuts the pyroxene, and the gneiss does not appear. Portions of the dyke are rusty, and the apatite occurs in chimney-form, at one place extending into the hill for about 20 feet but downward to an unknown depth. The apatite occurs as usual in the greyish-green pyroxene in close proximity to the other intrusive mass. There is no indications of any bedded structure either in the pyroxene or in the apatite, or of a vein structure in the latter, and on the sides of some of the pits small quantities of apatite are attached to the mass of the pyroxene showing the rock to be impregnated quite extensively at several places.

## NORTH STAR MINE.

Among other interesting places where the apatite deposits can be well studied may be specially mentioned the North Star mine on the east side of the Lièvre. Here the mining has been carried on principally on or near the crest of the ridge at an elevation of about 600 feet above the river which is four miles to the west. As the depth of the deepest shaft is in the vicinity of 600 feet the bottom of the workings are about at the river level. North Star mine.

The country rock is a reddish and sometimes greyish gneiss, with a strike of N. 15° W. and an east dip of sixty degrees. This is traversed by dykes of several kinds. At the south end of the area an opening has been made in a mass of greyish pyroxene in which a little apatite is visible. Further north a large vein-like, in places pockety, deposit is seen in the pyroxene with a north-west course going down nearly vertical, and the gneiss in the vicinity is much intersected by granite dykes.

Ascending the hill northerly towards the hoisting plant, the strike of the red and grey gneiss changes to north and south, with a high east dip, and a pit is seen where in the excavation the pyroxene occurs as a round chimney-like mass about 10 feet in diameter, the banding of the gneiss following closely around the mass of the intrusive rock, on all sides. The apatite occurs along the outer zone. Just to the east of this another dyke of pyroxene breaks through the gneiss along the line of stratification or banding and this carries small quantities of apatite with red calcite. The gneiss in contact is much shattered and carries pyrite. No apatite is seen in the gneiss, but it occurs with crystals of mica and pyroxene along the contact in the calcite. Dykes of pegmatite cut across the pyroxene. At the pit under the hoisting shed the crystals of mica seemed to follow more closely the smaller pegmatite dykes along the line of their intersection with the pyroxene.

At the principal opening of the North Star, which has a length of about 130 feet and a depth of over 600 feet, an interesting exhibit of apatite is disclosed. Three large pockets in the form of chimneys are seen which are connected by small stringers. This is near the crest of the ridge, and the apatite is continuous to the bottom of the shaft which is sunk in the mass of the pyroxene throughout. The mineral occurs near the contact with the gneiss on both sides of the main dyke but is very irregularly distributed at different point, sometimes occurring in immense pockets, while the connecting portions are often reduced to small strings. This condition of development appears to

prevail throughout. At the north pit the structure is a dome-like mass of the pyroxenic diorite which carries the apatite more or less disseminated, the pyroxene having the aspect of an intrusive body which has burst through the surrounding gneiss and tilted the latter from it in both directions. A similar structure is visible in several other pits, independent of the main mass of the pyroxene. In some of the smaller pits the apatite is associated with crystal of dark mica. Along a series of pits still further north a similar displacement of the enclosing gneiss can be seen. In places where the apatite is found in large bodies side spurs of the mineral are given off on either side, so that the conditions of its occurrence appear to very similar throughout the entire extent of the pyroxene development. Mica crystals are developed in the apatite near the outer contact, similar to occurrences of this mineral in calcite in the Gatineau district.

### SALETTE MINE.

Salette mine.

In this mine which is near the Lièvre river, the quartzite and gneiss are cut by green pyroxene and this in turn by white pegmatite, and the presence of the apatite is near the contact of the two intrusions.

### LITTLE RAPIDS MINE.

Little Rapids mine.

Of a somewhat different type from the North Star mine is the Little Rapids mine, which is about one mile east of the Lièvre river at the locks about 12 miles above Buckingham village. This was one of the first mines opened in the district, and mining was carried on by Mr. W. A. Allan in 1883, and continued for some years.

The country rock is the ordinary greyish and quartose gneiss which extends from the river shore eastward, and is cut by numerous dykes of diorite and granite. Where comparatively undisturbed the gneiss has strike of N. 40° E. with a N. W. dip of 50°. The pyroxene dyke in which the mine is located is large and has a direction of N. 10° E. with a dip to the east of 80 degrees. The width of the apatite bearing position of the dyke, which is near the contact with the gneiss, is from three to five feet, and crystals of mica are developed in the lower portion near the pyroxene contact of this zone. The west side of the cutting shows a wall formed of the banded edges of the gneiss and quartzite, and in the mass of the dyke are pieces of the gneiss which appear to have been caught up in the outflow. Dykes of pegmatite cut the gneiss and the pyroxene, several other dykes of the latter

occurring in the vicinity, in most of which the apatite is found. The workings reached a depth of about 220 feet, and the yield of apatite was large, the deposit like that of other places varying in thickness at different parts of the mine.

At the upper London mine which li s to the north of this, a similar occurrence of pyroxene and pegmatite dykes cutting and altering the gneiss is seen, the strata of the latter being bent over and displaced along the contact with the development of pyrite in many places* along the margin. The apatite occurs as a contact deposit near the contact of the pyroxene and the gneiss. A similar occurrence of sharp definition between the pyrozene and gneiss is seen in the other London mine which is on the side of the ridge near the Lièvre, and in the open cutting at this place the presence of the apatite near the contact can be well studied.

### THE AETNA, SQUAW HILL AND EMERALD

Aetna Squaw Hill and Emerald mines.

These three mines form a small group near the Lièvre river which when worked were among the largest and most important in the district. They occur near the crest of a ridge in which the development of the pyroxene and other intrusive rocks are largely displayed. The apatite frequently occurs at the intersection of the later dykes with the pyroxene, and frequently a considerable development of pink calcite is seen in the latter in which the apatite is found with mica crystals. The large development of apatite here is probably, as at the group of mines on the west side of the river at High Rock, etc., due to the presence of the intrusive masses. The shaft at the Aetna reached a dedth of 130 feet in 1893, or at about the close of the industry in this area. The apatite is often found along the course of some one of the diabase dykes which forms a foot wall and carries masses of pyrite near the contact with the pyroxene, and occasional very large crystals of apatite were here found. The name of " Crystal pit " was given to one of the principal excavations from the fact that the pit was at first sunk on the mass of the crystal itself for some feet. Similar modes of occurrence are seen at several of the other mines in this vicinity.

Glasgow mine.

At the Glasgow mine a shaft said to have a depth of 300 feet was sunk in pyroxene near the contact with the gneiss on a body of apatite with a reported thickness of five to six feet. Small quantities of pink calcite occur at intervals through which mica is disseminated with apatite and pyroxene crystals. The intrusive dykes are numerous, and intersect the gneiss in all directions and the apatite is usually found in bunches or pockets in these as elsewhere.

Philadelphia mine.

At the Philadelphia mine the cross contact of the pyroxene with the gneiss can be well seen, the course of the former being N. 40° E. with a dip S. E. 35°, while the strike of the gneiss is N. 20° W. with a N. W. dip, the intersection of the dyke with the gneiss being at an angle of about 60 degrees. Both red and green apatite are found in this as at several of the other mines in the district.

McLaren mine.

At the McLaren mine adjoining to the west, the gneiss is nearly flat as if thrust up and overlying a mass of pyroxene which is in turn cut by red pegmatite, in which the felspar has a purple tint. No mica was seen at this place.

From the above descriptions of some of the leading apatite deposits of the Liêvre, which might if necessary be greatly extended, the following conclusions may be reached.

Mode of occurrence of apatite.

1st. Where apatite occurs in large masses of pyroxene, which has been shown to be clearly an intrusive rock in the gneiss, and where this is cut by later dykes of pegmatite or diabase, the presence of the apatite is in close relationship to the occurrence of the later intrusion.

2nd. In the case of many of the smaller dykes of pyroxene the apatite occurs near the outer zone or in contact with the surrounding gneiss and is sometimes associated with mica and calcite, though not always so. In these cases the apatite frequently assumes the crystalline form, and the conditions approach those seen in many of the mica mines of Templeton and Hull.

3rd. The indications of the intrusive nature of the pyroxene in the gneiss, and of the later intrusions of diabase and pegmatite both red and white, are so clear as to warrant the assertion that when apatite is found in these rocks its presence is not due to organic agencies but to conditions belonging to the period of intrusive action.

Priest Creek mine.

To the north of the apatite belt already described there are several localities, such as the Priest Creek areas, in which apatite is found at several points and attempts have been made in former years to work some of these deposits. Apparently no great amount of success attended such efforts, and the present depressed condition of the industry, together with the distance from a convenient shipping point has interferred with their practical development. From the report by Mr. Obalski, for 1889-90, it will be seen that the mineral has been recognized in this direction in the townships of Bowman, Bigelow, Denholm, Derry, Hincks, Lochaber, McGill, Villeneuve and Wells, but practically no attempt has ever been made to ascertain the amount of mineral at most of these localities.

## The Templeton District.

The apatite mines of the Templeton district present certain features differing somewhat from those which have just been described. The country rocks are however practically the same, but in portions of the field there is a greater development of the crystalline limestones. Pyroxene dykes, often of large size, with others of pegmatite and diabase, are common. Templeton areas.

One of the features here seen is the occurrence of the apatite with a large development of mica crystals. In some of the largest mines, notably in the Blackburn, which for years was the largest producer in the district, this feature is especially well seen, and since the closing of the mine as a producer of apatite it has been regularly operated as a mica mine. In this respect the occurrences of these minerals more nearly resemble the conditions which are seen in the mines along the Gatineau river and throughout the mines in eastern Ontario.

In the Templeton district during the period of apatite mining, the principal mining areas comprised the following :— List of areas in Templeton

The Blackburn, lot 10, range XI, Templeton township. In addition this mining area included lots 7, 8, 9 and 11, same range.

The McLaren, lot 8, range XII ; S. ½ 7, N. ½ 10, range XI ; and N. ½ lots 4, 5, 6, range VII.

Lomer, Rohr & Co., largely engaged in milling rather than in mining directly.

Jackson Rae Phosphate Co., W. ½ lot 9, range X.

Canada Industrial Co. (C. Lionais & Co.) lot 16 range IX ; E. ½ lot 9, range X. (Post Mine) Société Française ; lot 3, range XIII, in addition to large areas in the Lièvre district.

Anglo-Canadian Co., lots 6, 7, range XIII (Battle Lake mines) ; and lots 9, 41, 42, 43, 44, 45, 56, Templeton Gore.

Templeton and Blanche river Co., lot 6, range XI.

The Grier area, S. ½ lot 3, S. ½ 4, and 7, range VII ; lot 7, range X.

Miller mine, S. ½ lot 2, range XII.

Murphy mine, S. ½ lot 12, and lot 6, Gore.

Several of these mines were opened at various dates ranging from 1880 to 1886. From some of these the output was quite large for several years but gradually decreased. The greater number of these belong to the class known as contact deposits, usually associated with

mica and calcite, the apatite often occurring in the form of crystals; but in some cases, notably in the Blackburn mine, the calcite is largely replaced by apatite through which the mica crystals are disseminated, and the ore body is in places very large. The occurrences are on the whole different from what is seen along the west side of the Lièvre, in that the masses of pyroxene are usually much smaller, and there is not the same close association of the apatite with the newer diabase or granite dykes.

### WAKEFIELD AND HULL MINES.

Wakefield and Hull areas.

In the southern portion of the township of Wakefield especially in ranges I and III, occurrences of apatite are frequent and have been worked quite extensively. Among the principal deposits are several in the vicinity of Wilson's Corner, all of which may be classed as contact deposits, the mineral occurring for the most part with mica and calcite.

Mines in Wakefield township.

Among these mines may be mentioned:—

Haldane's mine, lot 12, range I.

Moore's mines, lot 17, range I, and lot 18, range II.

Wilson's mine, lot 17, range II.

Gemmill mine, lots 22, 23, 24, range V.

Harris mine, lot 30, range IX.

Seybold mine, lot 18, range II.

Other mines in this district which have been opened and worked for mica to some extent show also the presence of apatite occurring in the crystalline form in calcite.

Mines in Hull township.

In the township of Hull, apatite deposits are found at many places, usually associated with mica in the same manner as the occurrences in Wakefield. Among the most important of these may be mentioned the following, which for some part of their history were mined for apatite and partly for mica.

The Scott mine, lot 15, range X.

Prudhomme mine, lot 9, range XII.

Davies mine, lot 9, range XI.

Gow mine, lot 10, range XI.

McLennan mine S ½, lot 10, range XIV.

Barbers mine, lot 16, range XVI.

Browns, and Fortin-Gravel mines, the former on lot 19 range VII, the latter on lot 18.

Haycock mine, lot 17, range X.

Connor mine, lot 14, range XI.

Snow mine, lot 14, range XII.

These are all on the west side of the Gatineau river.

On the east side in Hull township may be mentioned :—

Wilson mine, lot 13, range XVI.

Chubbuck mine, lot 12, range XV.

Burke mine, lot 1, range XIII.

Vavasour or Gemmill mine, lot 10, range XII.

Webster mine, lot 10, range XIV.

Apatite with mica and calcite.

From an examination of many openings made in these townships, from some of which considerable quantities of apatite were taken in the earlier years of the industry, it may be stated that, for the most part, the mineral occurs in the crystalline form associated with mica crystals in calcite near the contact of the pyroxene with the gneiss. Occasionally the apatite is found as pockety masses in the pyroxene itself as in the Lièvre district, but the size of such pockets is nowhere so important as in that area.

From the economic standpoint it may be questioned whether the mining of apatite from mines of this class can ever be permanently profitable. The amount of calcite and other rock which forms the vein filling necessary to be extracted to obtain merchantable apatite in quantity is large, and in so far as the exploitation of these deposits proceeded some twenty years ago, it was found that only the largest of these could be mined to profitable advantage. Many of them were opened by shallow pits and abandoned, others reached depths along the calcite filling of 150 to 200 feet, drifts being carried along the run of the pyroxene, but all were long since abandoned. Several were mined subsequently for mica, and in some cases this is still pursued as in the case of the Vavasour mine and others, in which case the apatite extracted with the mica is saved and sold as a by-product.

In some of the mines along the Gatineau which are opened on large masses of pyroxene as at the Cascades, the Nellie and Blanche, the Cassidy mine, &c., while mica has been found in large pockets occurring thus after the manner of the apatite pockets along the Lièvre, but small indications of apatite itself have been found. The

reason for this is not quite clear, since there is frequently the same occurrences of diabase and granite dykes in both areas. Usually however at all the mining areas in the Templeton and Gatineau districts the two minerals, mica and apatite are closely associated.

Output for these areas.

While the total figures of the output from the different mining centres north of Ottawa are not available for publication as regards the different mines, it is clear that, by far the great bulk of the output for the fifteen years for which mining returns are furnished came from the large group of mines in the Lièvre district, and that the only truly large producer outside this area was the Blackburn mine in Templeton. The output from the Hull and Wakefield areas aggregated but a few thousand tons as compared with the total recorded output for the Quebec mines of 270,000 tons between the years 1878 and 1894 both inclusive, and a total output from the mines of eastern Ontario for the same periods of only 24,767 tons.

## MINES IN ONTARIO.

Ontario deposits.

Apatite mining commenced in Ontario at a comparatively early date. As far back as 1860 a shipment of 100 tons was made from the mines in the township of North Burgess; or about 10 years before actual mining operations were commenced in the province of Quebec.

The mining centres in this province may be described under three heads as regards locality, viz.: those of North Burgess between the Rideau lake and the town of Perth; those of the county of Renfrew; and those of the Kingston district, which includes the townships of Bedford, Storrington and Loughborough.

Renfrew township.

In the county of Renfrew the apatite deposits are practically confined to the townships of Ross and Sebastopol. Of these the mines which were opened nearly 25 years ago are the following:—

Elliott's mine, lot 7, range I, Ross, the mineral occurring in disseminated crystals in calcite, with other crystals of pyroxene, scapolite and titanite.

Cole's mine, lot 13, range VI, Ross, apatite in crystals in calcite.

Park's mine, lot 23, range XII, Sebastopol, crystals in calcite.

Meany's mine, lot 31, range XI, Sebastopol, in crystals with pyroxene in calcite.

Smart's mine, lot 31, range X, apatite in crystals in calcite.

Turner's mine, on island in Clear lake, apatite in crystals in calcite.

All these deposits are clearly of the vein type; and while in most cases are of small economic value, except as mineral localities, from several of the openings, notably in that south of Eganville, a large quantity of apatite was extracted, some of the crystals being of large size. Nowhere was there any indication seen of the large pockety deposits of the massive variety found north of the Ottawa.

In the Burgess district, the occurrences of the mineral are frequent and in some of the mines were quite extensive, so that this area was an important producer for some years. The mineral is found both in the contact vein form and as pockets in the mass of the pyroxene when such dykes are of good size. The greater number of the openings which have been made in the rocks of the district are however sunk on the vein or contact deposits.

In Gordon Broome's report, 1870-71, and in Vennor's report, 1873-74, a large amount of detailed information as to the working of the North Burgess mines is given with full descriptions of the numerous openings in the several areas. The greatest number of these are found on range VIII, from lots A, to lot 7, on the north side of Otty lake. Mining operations were carried on at intervals on lots 11 and 12, range VII; on lots 9, 10, 11, 12, 18, 19, 20, range VI; on lots 4, 8, 9, 10, 16, 19, 20, 21, range V, which include practically all the known deposits in this township. In the township of North Elmsley to the east, apatite is found on lots 25, 26, 27, range VIII, and on lot 30 range VI. In South Burgess it is found on lot 2, range IV. North Burgess.

It is not necessary to repeat here the various descriptions of the several areas in this district as contained in the reports just mentioned. From the details there given at the date of the workings, as well as from recent examination it is evident that the occurrences in this area are similar to those seen in the Wakefield and Gatineau districts rather than to those which occur on the Lièvre. While mining from surface pits, at slight expense, produced a fair amount of high grade apatite, mostly in the form of crystals, it was found that the expense of sinking shafts and driving drifts was usually too great to warrant long continued operations, so that while the surface openings were very numerous, mining gradually declined as the more readily accessible deposits were extracted. Several of the most important areas have since been re-opened for mica and the associated apatite has been saved as a by-product, but during the past year only one mine of mica was being worked.

## Mines of the Kingston district.

Kingston district.

In the mines of the Kingston area, which extended as far north as the vicinity of Sharbot lake on the Canadian Pacific railway, similar conditions have been observed to a large extent. Some of the deposits are of larger size than any yet found in the Burgess district and have yielded a large amount ef excellent apatite.

In the township of Bedford, workable deposits hava been opened up near Bobs lake on lots 32, 33, 34, range VII; lot 28, range VIII; lots 4 and 6, range XIII; lot 3, range XII; lot 7, range VII; lot 6, range IV; lot 4, range II.

### Township of Storrington.

Lot 8, range XV; (Buck Lake mine); lot 23, range XV, (Opinicon lake.)

### Township of Loughborough.

Lots 11, 12, 14, 16, range VIII.

Lots 4, 5, 10, 11, 12, 13, 15, 17, range IX.

Lots 7, 8, 10, 13, (Foxton mine); 19, 24, range X.

Lots 8, 9, 10, 15 24, range XI.

Lots 19, 22, 24, range XII.

Lots 24, 25, range XIII.

### Township of North Crosby.

Lot 19, range II; lot 20, range III; lot 21, range X; lot 29, range IX.

### Township of Oso.

Lot 6, range I; (St. George Lake mine.)

Lots 1 and 2, range V; (Crow lake.)

Lot 14, range VI; lot 4, range VIII.

### Township of Hinchinbrooke.

Lots 29, 30, range I. (Eagle Lake mines. Boyd Smith.)

Character of these deposits.

The above list comprises most of the mining areas in the Kingston district. In some, as on the Boyd Smith property, the apatite is

found in pockety chimneys similar to certain occurrences in the Lièvre district, but in the greater number it is usually associated with mica and calcite. The country rocks of all the area are practically similar throughout, consisting of the usual grey and reddish gneiss, with some quartzite and limestone, all of which are traversed by dykes of pyroxene, diabase and pegmatite. Several of these mines were opened to depths of over 200 feet as at Opinicon and Buck lakes, while in other cases the work done was by shallow pits. The great bulk of the output was apparently from the crystallized variety, though some quite large deposits of the massive variety, both red and green were extracted.

It is impossible to obtain the details of the workings at most of these localities. At the time of the recent visits the mining had long been abandoned, the excavations were full of water, and the information regarding the structure and nature of the deposits could only be obtained from the surface workings and from the dump material.

Calcite replaced by apatite.

At several of the mica mines, notably the Sydenham mine, of the General Electric Co., formerly worked for apatite, (the Smith and Lacey) some interesting features were observed. The mica was found to occur sometimes in the mass of the pyroxene after the manner of apatite elsewhere, and sometimes as crystals in calcite associated with crystals of apatite. In places in the same shaft the calcite was found to give place to apatite, and in this case the mica was disseminated in the latter in the same manner as in the calcite.

In many of the localities throughout the district the quantity of the mineral was not sufficient to warrant an extensive mining plant, and the work of drilling and hoisting was carried on for the most part by hand labour. The extraction of the mineral was often done by the farmers of the district, who in spare time from their regular farm work were able to extract considerable amounts of the mineral in a comparatively simple manner; but when the surface pits reached a depth beyond which this process was not practicable the mining was abandoned in favour of some more accessible locality. In certain places where the apatite crystals were very thickly distributed through the calcite their extraction was rendered possible and profitable for a time; but when, as is often the case, they were sparingly disseminated the expense attending the mining was such that all possible chance of profit was eliminated.

Isolated occurrences of apatite have been reported from several townships other than those mentioned, but apparently the quantity in

these localities was never sufficient to warrant the expenditure of much capital in their development.

As an illustration of the rise and decline of one of the leading mining industries of the province of Quebec and eastern Ontario the following figures taken from the Report of the Mining branch of the Department for 1895 may be given. The period extends from 1878 to 1894, both inclusive, the amounts prior to the first mentioned date being for Ontario, probably not more than 1,000 tons annually.

Output.

## EXPORTS OF PHOSPHATE.

| Year. | Ontario. | | Quebec. | |
|---|---|---|---|---|
| | Tons. | Value. | Tons. | Value. |
| 1878..... | 824 | $12,278 | 9,919 | $195,831 |
| 1879..... | 1,842 | 20,565 | 6,604 | 101,470 |
| 1880..... | 1,387 | 14,422 | 11,673 | 175,664 |
| 1881..... | 2,471 | 36,117 | 9,497 | 182,339 |
| 1882..... | 568 | 6,338 | 16,585 | 302,019 |
| 1883..... | 50 | 500 | 19,666 | 427,168 |
| 1884..... | 763 | 8,890 | 20,946 | 415,350 |
| 1885..... | 434 | 5,962 | 28,535 | 490,331 |
| 1886..... | 644 | 5,816 | 19,796 | 337,191 |
| 1887..... | 705 | 8,277 | 22,447 | 424,940 |
| 1888..... | 2,643 | 30,247 | 16,133 | 268,362 |
| 1889..... | 3,547 | 38,833 | 26,440 | 355,935 |
| 1890..... | 1,866 | 21,329 | 26,591 | 478,040 |
| 1891..... | 1,551 | 16,646 | 15,720 | 368,015 |
| 1892..... | 1,501 | 12,544 | 9,981 | 141,221 |
| 1893..... | 1,990 | 11,550 | 5,748 | 56,402 |
| 1894..... | 1,980 | 10,560 | 3,470 | 29,610 |
| 1895..... | ..... | ..... | 250 | 2,500 |
| | 26,766 | $260,874 | 280,000 | $4,752,388 |

NATURAL SCIENCE
N
126
13
903
13

✓ 882

GEOLOGICAL SURVEY OF CANADA
ROBERT BELL, D.Sc. (CANTAB.), M.D., LL.D., F.R.S., I.S.O.

# MINERAL RESOURCES OF CANADA

## BULLETIN

ON THE ORES OF

# COPPER

IN THE PROVINCES OF NOVA SCOTIA, NEW BRUNSWICK AND QUEBEC.

BY

R. W. ELLS, LL.D., F.R.S.C.

OTTAWA
PRINTED BY S. E. DAWSON, PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1904

No. 882.

THE UNIVERSITY OF MICHIGAN LIBRARIES

Natural Science
Library
T N
226
.A3
1903
v.13

ON THE ORES OF

# COPPER

IN NOVA SCOTIA, NEW BRUNSWICK AND QUEBEC.

By R. W. Ells.

The presence of copper has been ascertained in nearly all parts of the Dominion of Canada, with the exception of what is known as the prairie section and in the great Lower Laurentian areas on either side of Hudson bay. In the far east its occurrence around the shores of the Bay of Fundy was recognized nearly 300 years ago by the early French explorers in 1608, and mining has been carried on at intervals in the adjacent province of New Brunswick for more than half a century. The copper deposits of Quebec are in many places large and important and have been mined for the same length of time. Those of Ontario have long been exploited, in some cases with a fair amount of success, while in the western portion of the Dominion copper mining has been carried on with varying success for some years. In the far north the copper of the Barren Lands was reported by Arctic explorers nearly a century ago, but owing to the great difficulties connected with exploration, the real importance of these deposits, as on the Coppermine river and in the rocks of the west side of Hudson bay, has never been fully ascertained. Early references.

In the treatment of this subject it is proposed to discuss the distribution of these ores by provinces, beginning on the east or Atlantic portion of the Dominion, and to consider first of all the known occurrences in the province of Nova Scotia.

A review of the literature pertaining to the copper deposits of eastern Canada, more particularly as relates to this province and to those of New Brunswick, where the occurrences present many similar features, reveals the fact that, although the presence of ores of various kinds has been known and referred to in many publications for nearly a century, and large amounts of capital have been expended in developing what appear to be promising localities, but little of economic value in the way of direct profits, has as yet resulted.

## Nova Scotia.

Copper ores of Nova Scotia.

In this province, though the presence of native copper was observed in the igneous rocks of the Bay of Fundy by Lescarbot shortly after the arrival of the early French explorers in that country, in the development of that province but little attention was directed to the nature of such deposits for more than two centuries. At a later date, 1828-29, the presence of this mineral was fully noticed by Messrs. Jackson and Alger who made a somewhat extended examination of the igneous rocks along the Bay of Fundy, and in his report, 1836, Dr. Gesner called attention to the presence of ores of various kinds in different parts of the province. Numerous references were also made to the presence of these ores by later writers, including Professors How and Hind, Messrs. Poole, Gilpin and others, in papers to different scientific societies and in reports to the provincial government. Since the advent of the Geological Survey, in the eastern provinces, subsequent to the period of Confederation, careful attention has been given to the occurrence of all minerals of economic value, and the localities where such minerals have been observed have been pointed out. Descriptions of many of these may be found in the several reports by Mr. Hugh Fletcher for nearly thirty years. From a study of the available information relating to this subject the following synopsis is presented. Certain information as to details of mining and economic results are of necessity omitted, since as regards the working of many of these deposits during the last forty or fifty years there is very little information of value to the general public to be obtained.

The copper ores of the province present considerable variety and occur under widely different geological conditions. In the broad sense they may be classed under four general heads.

Mode of occurrence.

1. Those pertaining to crystalline rocks, mostly felsitic in character, and occurring at a number of points in the eastern part of the province, especially in the Island of Cape Breton.

2. Those found partly in connection with intrusive rocks which cut Devonian and Silurian strata of the eastern part of the province; and as contact deposits in these formations.

3. Those which occur in rocks of Carboniferous age, more especially in the upper Carboniferous or Permian beds in the area south of Northumberland strait. These ores evidently owe their presence to the action of organic matter in the form of plant remains upon copper in solution.

4. Those which are found in connection with the great trappean outflow of the North Mountain range and in similar rocks on the north side of the Bay of Fundy, from Five islands westward to Cape d'Or. In this case the copper is principally in the pure or native state, sometimes becoming green on the surface through oxydation.

### THE ORES OF THE FIRST DIVISION.

Ores of the first division.

The ores found in connection with the felsitic rocks of Cape Breton and elsewhere are usually in the form of copper pyrite associated with iron pyrite and sometime with galena and zinc blende. At some localities gold has also been found in small quantities. Most of the occurrences in this district, in so far as described by Mr. Hugh Fletcher, in his reports to this Department, are undoubtedly small in extent and give but little promise of successful returns from their development. In some localities, notably at Coxheath and at Cheticamp, certain conditions have occurred which have produced a greater development of these ores, and at the former a large amount of capital has been spent in mining plants, for which as yet but small returns have apparently been realized. At Cheticamp the ores are found associated with schists, generally felsitic, and there is a greater diversity in their character, some of the ore-bodies being of large extent. Usually however the copper pyrite is found along joints or fissures in the shattered felsite rock which is generally reddish or grayish in colour, resembling much of that found in southern New Brunswick and in parts of the felsite belt in the northern area of that province. In geological position, they have been referred to the pre-Cambrian series. Sometimes the ore occurs in irregular quartz layers which traverse the felsites.

Among localities where these ores have been found in the Cape Breton district in varying amount may be mentioned the following, taken from Mr. Fletcher's reports.

Gabarus bay.

Caribou Marsh road, two miles from Gabarus bay. Copper pyrite in compact felsite, nowhere apparently in paying quantity. Eagle head, Gabarus bay; deposits of rich ore in the form of pyrite and mined to some extent about 30 years ago. The felsite contains quartz layers, one band reported to have a breadth of four feet which was worked in the old shaft, but the prospect of finding a valuable deposit does not seem greatly improved. Associated with the feldspar and quartz, a band of whitish green soapstone was found in shaly layers by Mr. Angus Campbell of Sidney, with arsenical pyrites, bismuth-glance, iron pyrites, molybdenite and traces of gold. Report Geol. Sur. 1877-78, p. 29 F. The shaft is reported to be sunk to a depth of 75 feet.

In Gilpin's report on Mines in Nova Scotia, 1880, the belt of laminated quartz is said 'to have a thickness of 25 feet, intermixed with soft felspathic rock. The quartz layers are of varying thicknesses and carry the ore in irregular quantities..... Shafts have been sunk at the Eagle Head and French Road deposits by Mr. F. Ellershausen, and it is understood that well-defined and promising veins have been found. Work has been abandoned for some years.

Boulaceet harbour.

In the section between Burnt point and Boulaceet harbour, copper pyrite in small quantity is found in veins cutting a grey micaceous laminated quartzite of the crystalline series; and at the silver mine on this harbour a rich pocket of galena, with copper and iron pyrite holding some silver and gold, was found in a small vein of ½ to 4 inches thick and mined to some extent by Mr. A. Cameron of Baddeck. Report Geol. Surv. 1876-77, p. 407.

Washaback.

Similar occurrences are recorded from the Washaback district, the copper and iron pyrite being in irregular quartz veins with blende and galena. In a conglomerate at Washaback near Crow point copper ores are found, probably induced through the agency of plant stems on the metal in solution, which have given by assay appreciable quantities of gold and silver. Gilpin, 1880, page 80.

In the felsite of Blue mountains small quantities of copper occur, as also in the White Granite hills near French river. The ore is in the form of pyrites with iron pyrite, but the amount appears to be of small economic importance.

At Three Island cove, copper and iron pyrite are found as mere specks only, in quartz veins crossing black and gray slate and sandstone and the deposits are of no apparent value.

Various localities in Cape Breton.

At Grantmire brook, iron and copper pyrite are found in layers in a compact gray and pink felsite, the ores yellow and purple, weathering into the green carbonate.

In a brook just west of Morrison road near West bay, traces of green carbonate of copper were found in a quartz-felspar rock, associated with soft soapy calcareous rocks like those at Coxheath and Gabarus.

At North-east harbour and Skye mountain, copper pyrite in small veins cutting felsite rocks, mined to a small extent.

Gillis Lake road, yellow and purple copper pyrite, scattered through a large mass of compact and brecciated felsite; in places calcareous and full of a soft soapy talcose material. Some mining was done at this place by Mr. Burchill.

Brooks near the Coxheath road at Battleman's above the mineral spring, traces of copper ore.

Green island; specks of iron and copper pyrite in small quartz veins cutting dark gray felsite; of no economic value.

Shore east of Big harbour; veins of copper ore traversing diorite, schist and gneiss; have been worked to some extent.

Stewarts brook; small specks of copper pyrite in veins and beds of limestone, with schist, felsite, quartzite and diorite.

Jerome brook; copper pyrite in quartz-veined syenite and compact red felsite with diorite. Mined to some extent.

On mainland, west side of Great Bras D'Or lake, opposite Man of War point, copper pyrite in a compact bluish-gray gangue; the ore by analysis gave, copper 14·28 per cent.

Coxheath mountain; probably the largest of these deposits at present known in this district. Opened first about twenty years ago and worked at intervals since that time. A large amount of capital expended in development works and mining plant. The ores are copper and iron pyrite in bodies sometimes of large extent, occurring in felsite which is often much fissured and broken; the ores carry small amounts of gold and silver. In the deposit there is a small quantity also of calcite and quartz. The first work was done in 1880, and four shafts have been sunk to depths of 300, 420, 100 and 45 feet. Numerous trenches and trial pits have also been made, in order to prove the extent of the deposit. The last shaft was sunk in 1892. Work has been suspended for several years. When examined by H. P. Brumell in 1892 he reported the cupriferous belt as 1,500 feet thick in which ore-bodies occurred in veins from two to twenty feet wide. The underground workings consist of tunnels and drifts. A large quantity of ore estimated at from 2,000 to 3,000 tons has been extracted, portions of which have been hand-picked and partly crushed and jigged, but apparently no shipments of the ore have been made with the exception of small amounts for sampling. The quantity of copper in the ore is given in the last report of the Nova Scotia Department of Mines as seven per cent, from a sample taken across the ore pile. The expenditure of money in the development has been very large, but the area has not yet been placed on a paying basis. Coxheath mountain

George River mountain; R. A. L. Watson's area, chalcopyrite, some of high values.

George River mountain, Alex. Matheson area, chalcopyrite.

French road, Cape Breton Co.; J. A. Mackenzie & Co., chalcopyrite.

Cheticamp mines.

Cheticamp. The copper at this place was referred to by Mr. Fletcher in several of the early reports on this district as far back as 1882. He says of the locality (Report, 1882-84, p. 95 H.) 'For some years prior to 1865 a company was engaged mining for copper ore at Cheticamp, and in 1864, about 12 men were employed. A shaft was sunk to a depth of 106 feet and connected with an adit 410 feet in length. An air shaft 30 feet in height was also cut from the adit-level to the surface of the ground, but not proving productive the works were discontinued. They are situated in the vicinity of the trap and sandstones at the base of the Carboniferous. Professor How mentions that green and blue carbonate of copper, gray and yellow copper ore in calcite and chrysocolla are found at Cheticamp, probably at this mine or at Jerome brook, as well as perfect crystals eight inches long of red feldspar in the pre-Cambrian syenite of the neighbourhood.'

Quite recently the property has been taken up by the Eastern National Copper Co. which has begun development work at Grandin brook. L'Abime river. The ore which is chiefly chalcopyrite occurs in schists, and the ore-bearing zone is said to have a breadth of 70 to 100 feet, but the present operations are confined to a thickness of 10 feet. The ore is reported to be mixed with galena and other minerals, and to show a small percentage of gold and silver. The copper contents run from $2\frac{1}{2}$ to 5 per cent, with an average of 3 per cent. At present the work on the property is only in the development stage.

Adjoining this area is another known as the Richfield Mining Co. which is developing another ore-body of presumably similar character. Along this shore of the island similar pyritic deposits are found in small quantity at several points north of Cheticamp, as at Poulet cove, near Money point and at Cape North. These are practically all copper pyrites in felsitic rocks.

From the evidence as yet presented regarding these pyritic areas, it would seem that the occurrences at most of the localities mentioned are too limited in extent to be of much economic importance. The largest ore bodies appear to be at Coxheath and near Cheticamp.

## ORES OF THE SECOND DIVISION.

Ores of the second division.

The copper ores of the second division are for the most part contact deposits occurring near intrusive masses of diorite or other igneous rocks and pertain to sedimentary formations including Silurian, Devonian or Lower Carboniferous strata, at the contact of the limestone and underlying conglomerate.

Of the latter, Fletcher mentions the occurrence of copper-glance, oxydized to carbonate, at Irish cove, Washaback, Middle and North rivers, Cape Breton. The ore occurs often as impregnations in the conglomerate at the contact of the limestone. An analysis by Hind shows a small percentage of gold in this ore.

Polson Lake mines.

The Polson Lake deposits and those of Lochaber, about four miles distant, Antigonish county, appear to come under this class. This area is well described by Fletcher (Report, 1886, pp. 119-120.) The ores apparently occur in Devonian slates, in a series of veins associated with spathic iron ore, which cut red and black slates and quartzite and are broken across by diorite dykes. In Gilpin's report, 1880, it is stated that six of these veins have been located and partly opened up, varying in width from $1\frac{1}{2}$ to 6 feet, carrying copper pyrite with erubescite and carbonate. The copper contents vary and by assay amount in places to 31·25 per cent of metallic copper. The properties have been developed to some extent, but no mining has been done in the area for some years. It is probable that a close relation exists between the ore bodies and the intrusive dykes of the district. At the Lochaber mine a whitish granular diorite or granite is found, which, as at Polson lake, breaks through the purple slates.

Mines in Cape Breton.

Some of the occurrences at Cheticamp are also apparently of this nature where the ore is found at the base of the Carboniferous near the trap dykes; and at Jerome brook the ore is sometimes associated with a dioritic mass, and in places changed to the green carbonate at the surface. The vein at this place sometimes has a thickness of a foot or more, but is irregular and the deposit is not persistent.

On the Great Bras D'Or lake, in the brook east of Big harbour, (Point Bevis) quartz veins in diorite carry small amount of copper with galena; and on the shore of Ste. Anne harbour there are small irregular veins of calcite and quartz, holding copper pyrite, hæmatite and galena, which were tested some years ago by Col. Bingham and others.

Mines in Eastern Nova Scotia.

Traces of copper ore are also found on McLean and Stewart brooks, and in Big Intervale of Margaree, but so far as known are of no economic value. In the Stewart brook the rocks are felsites, hornblende and mica schist cut by diorites, with beds of crystalline limestone.

At Pomquet forks, in a series of gray flags, slates and marly shales, in which plant remains are sometimes found, the stems are occasionally converted into coal and sometimes into green carbonate of copper and gray sulphide. This occurrence is similar to those observed in the

Various localities.

Upper Carboniferous or Permian rocks of Colchester and Pictou counties.

At Knoydart brook, gray and green flaggy sandstones with plant stems, present similar deposits at several points.

On Brierly brook, deposits of copper are found near the contact of green conglomerate and limestones of Lower Carboniferous age, and have been mined to a limited extent.

At Ballentyne cove the green carbonate is seen in a similar conglomerate, overlaid by a light gray limestone. The ore, found mostly at the contact, is yellow and purple copper pyrite, seen at a number of points and has been worked at intervals for some years. Near the upper end of the Ohio river a mass of brecciated felsite occurs beneath the Lower Carboniferous limestone with deposits of copper pyrite, blende and galena. The rocks are greatly broken up, and according to Gilpin the ores carry small amounts of gold and silver.

On the Arisaig shore at the pier, there are small irregular veins carrying copper and iron pyrite with some galena, as also at a point in rear of the chapel at this place. On the Mill brook, crossing the St. Mary road above Eden lake, a small irregular vein of calcite is seen which carries small specks of copper pyrite.

On McAllister brook near Guysborough, specks of copper pyrite are seen in a greenish or black brecciated rock, filled with threads of quartz.

From the descriptions of these areas it would seem that most of them are of little economic value, and that the largest are those found in the Lochaber and Polson Lake district. These have been worked at intervals for some years but apparently without much success.

Other occurrences are found in the vicinity of McLellan mountain, as small pockety crystals of copper pyrite near the contact of Cambro-Silurian slates and igneous rocks. At Rocklin mills traces of ore are seen in Devonian slates; in minute quartz veins on the West branch of Middle river; in a brook near Pembroke, and elsewhere, all being associated with Devonian slates but of no apparent value.

### THE UPPER CARBONIFEROUS DEPOSITS OF THE STRAIT SHORE.

Ores of northern Pictou, Colchester and Cumberland Cos.

The presence of ores of copper, including gray sulphurets and carbonates in the gray and red shales and sandstones of the Upper Carboniferous, or as it is sometimes called the Permian formation, which

is extensively developed in portions of Pictou, Colchester and Cumberland counties, has long been known. They have been referred to in the reports by Jackson and Alger as far back as 1828, by Gesner and Dawson, and later by the officers of the Geological Survey. The associated rocks extend for many miles along the south side of Northumberland strait which divides Nova Scotia from Prince Edward island, where a similar geological formation occurs in which also at several points traces of the same ores are recognized.

Attempts have been made for half a century to mine these ores, but without much success. Within the last dozen years these operations have assumed larger proportions by the establishment of well organized companies and the erection of a more systematic mining plant, so that a large amount of capital is now invested in this direction in the attempt to put the extraction of these deposits on a paying basis.

Copper deposited through organic agencies.

The ores are mostly in the form of vitreous or gray sulphurets and green carbonates, and are often associated with jetlike coaly matter or lignite which is evidently due to the alteration of plant remains, the mineral being apparently deposited through the agency of the organic matter of the plants upon copper in solution. The deposits are found over a very wide area of these rocks and at a great number of points both in Nova Scotia and in New Brunswick where also attempts to mine similar ores have been carried on for some years.

Among localities in Nova Scotia where these ores are found may be mentioned the following, taken from the Reports of the Geological Survey and the Department of Mines, N.S.

Localities.

East river of Pictou near Hopewell; West river near Durham; French river; Waugh river; Caribou river about eight miles north of Pictou; Wallace river at several points; Tatamagouche; Pugwash; Chisholm brook and Canfield creek, Pugwash river; Athol; Oxford; River John; Salmon river; Malagash point; Doherty creek; River Philip; Fox harbour; Gulf Shore; New Annan; Wentworth; Henderson settlement; Nappan and Maccan. The above list shows the widespread nature of the conditions under which these ores have been deposited. Probably a closer search will disclose similar occurrences at other points.

These ores are usually found in beds of argillaceous sandstone and conglomerate, and sometimes in the associated red and gray shales. They occur as nodules and irregular seams or layers of the gray ore, deposited upon carbonized plant stems. The percentage of copper is high, amounting at times to seventy per cent of the metal. The

scattered nature of the deposits has however, so far been very much against their economic exploitation, both in this province and in New Brunswick.

Considerable sums of money have been spent in mining these ores on the French, the Wallace and Waugh rivers, as well as elsewhere, but the actual returns have never been published.

As an illustration of the mode of occurrence of these deposits the statements given in Gilpin's report, Deptartment of Mines, Nova Scotia, 1880, relating to the French river deposits above Tatamagouche may be here quoted.

French River ores.

'On the west side the gray sandstone beds near the top of the bank, carry the nodules disseminated through them to a depth of about 4 feet, the principal deposit being in a dark gray bed from 8 to 10 inches thick. Owing to the action of subaerial agents, the bed has a greenish cast, and the nodules are coated with carbonate. The nodules are on an average small, not larger than cherries, though some have been found weighing one pound and a half. When I visited this locality the drifts had so fallen in that it was impossible to estimate the apparent extent of the deposit, but from what was to be seen, it appeared not improbable that the nodules were not equally disseminated throughout the bed in which they were found, but are collected together, as at eddies or banks in the sandstone deposit. Below the gray beds, come beds of a reddish colour, and below them, close to the river's edge, other gray beds in which are the remains of plants, the tissue of which has become filled with copper pyrites.'

As an illustration of the amount of ore that can be obtained from these deposits it may be quoted from the same report as follows:—

'1876-77, the work of twelve men produced, according to statement of Mr. Prendergast, the manager, some 36 casks of ore, each averaging about 900 lbs. Subsequent work for two months yielded 6 more casks, averaging 800 lbs. each, or a total of 18½ tons, valued in New York at $120 per ton. The excavations made extended along the bank about 400 feet, and inland for over 200 feet; in length they measured nearly 2,000 feet.'

While operations have been carried on in this area at a number of places within recent years there appears to be no means available by which actual estimates of profit or loss from such work can be made.

From the last report of the Department of Mines, Nova Scotia 1904, the following data are given as to companies now or recently operating in this district.

Chalcocite and malachite. Hon. S. H. Holmes lease, Caribou river, Pictou Co. Deposit known for a considerable time and a fair amount of prospecting has been done. Some ore extracted by the Copper Crown Co. Caribou river.

Chalcocite nodules. Colonial Copper Co's mine, French river, 4 miles south of Tatamagouche; worked at intervals for 60 years by different parties. Now owned by the Colonial Copper Co. The property has been well prospected, and a number of tunnels, shafts and boreholes have been driven and put down. At present idle.

Chalcocite and malachite with lignite in sandstone. W. A. McPherson's mine, John Chisholm brook, Pugwash river, Cumberland Co. Prospected by Messrs Chisholm and McPherson. Four trial pits and a tunnel are on the property. The copper-impregnated sandstone beds are supposed to have a thickness of 12 feet and are said to have been proved on the strike for over 100 feet. Four or five tons of chalcocite were shipped to Boston and some tons are now on the site. Pugwash area.

Chalcocite, and malachite, in sandstone. W. A. McPherson's claim Canfield creek. This deposit, prospected by Mr. McPherson in 1902; sank shaft 25 feet and a quantity of ore was taken out.

Chalcocite, malachite, &c. in sandstone. Amos Blenkhorn mine, Acadia Copper Co. between Nappan and Maccan, Cumberland Co. Copper found here about ten years ago. Five years ago, a good deal of prospecting done and a timbered slope about 80 feet long, dipping southward about 47 degrees, was sunk and a few tons of picked ore shipped to the Copper Crown smelter at Pictou. Ore reported to assay from 5 to 46 per cent metallic copper. Associated with it are argentiferous galenite, azurite, sulphides of iron and copper, also lignite; gold is said to have been present in some of the assays. Property now unworked. Maccan and Nappan.

Other occurrences of these ores are taken from several reports. They include the shore between Cape John and Toney river; at Dewar river, Scotchburn brook; River John and Plainfield brook near the forks; and at other points in the vicinity. These occurrences are all similar to those just described.

### COPPER IN THE TRAP ROCKS OF THE NORTH MOUNTAIN RANGE.

The copper of this range of rocks which include several outliers on the north side of Minas basin and the Bay of Fundy, has been referred to in several early reports. It was noticed by Lescarbot, 1608, by Ores in the Trap formation.

Jackson and Alger, Gesner, and others. The observations of these early writers apply more particularly to the locality known as Cap d'Or on the north side of the bay, where scales, grains and small irregular veins of native copper are seen in certain bands of the trap formation, and from the bright yellowish-red colour of the mineral, these apparently led to the inference that gold was present and thus gave the name to the locality.

Character of rock.

The trap rocks of this district consist of several kinds, including heavy layers of the columnar variety, some of the columns being curved and others upright, sometimes forming a perfect floor along portions of the beaches. These are often overlaid by massive traps, and sometimes by beds of trap ash, often highly amygdaloidal and holding a fine variety of zeolites in great perfection as regards their crystallization, so that this part of the province has long been a favourite area for mineral collectors.

Cap D'Or mine.

At Cap d'Or the native copper can be readily seen in certain beds exposed in the coast section at the end of the point and along the east shore in the direction of Spencers island. The containing rock is often a reddish-brown trap-ash through which the metal is disseminated, both as minute grains and in small pieces like fish-scales, as well as in small and irregular veins. Occasionally pieces of several pounds weight are obtained. An attempt to mine these ore-bodies was made by a Halifax company about thirty years ago, near Horse-shoe cove two miles north-east of the end of the cape, but the place was soon abandoned.

The height of the cliff is about 350 feet, and several copper-bearing zones are found. On the west side of the cape the columnar trap at the base is overlaid by the copper-bearing reddish, slightly porphyritic and sometimes amygdaloidal trap which sometimes has a breccia or trap conglomerate in its lowest part. There is sometimes a marked aspect of stratification in the several series which make up the face of the cliff with an apparent dip to the east on the west side, while on the east side near Spencers, the dip appears to be reversed. Zeolites are more abundant on this side than on the west part of the cape. After passing the high promontory which forms the south side of Spencers cove the red Triassic sandstones come in and extend north to the contact with the older series of the main shore.

Character of work done.

In 1900 the Colonial Copper Co. acquired a large area at this place amounting to 2300 acres, and proceeded to erect a mining plant for the extraction of the native copper from the trap. A large amount of work has been done, involving the expenditure of several hundred

thousand dollars, in development work and machinery. A concentrating plant has also been erected. In the last report of the Department of Mines, Nova Scotia, 1904, it is stated that 'No. 1 lode shaft has a length of over 371 feet with over 1000 feet of tunnels and drifts. No. 2 lode slope going south 326 feet and another slope going north 300 feet with 800 feet of tunnels and drifts. No. 3 lode shaft, depth 180 feet with tunnels and drifts of over 300 feet. A railroad has also been built from the mines to the mill. The native copper occurs here in veins and joints in the Triassic trap.' No actual statement of cost of winning the metal is apparently obtainable.

Other occurrences on the North Mountain range.

Similar occurrences of the ore are found at a number of points in the trap area. Thus on the south side of the Bay of Fundy, a cupriferous basalt is met with at the mouth of Bishop brook, three miles east of Margaretville, which was opened to some extent by a short adit from near the water line but soon abandoned. Reference has also been made by Professor Bailey in his Report on western Nova Scotia, (Vol. IX, 1896, p. 140 M.) to the presence of copper in these rocks in Annapolis and Digby counties, and pieces of native copper of several pounds weight have been found on the beach. On the north side of Minas basin the metal is also found in small quantity at Five islands and at Cape Sharp. In all these places the quantity present does not appear to warrant the erection of a mining plant, the deposit at Cape D'Or being the most promising in the entire district.

Among other places which have been mentioned in various reports as containing ores of copper are East Dalhousie, Kings county, where quartz cuts across the granite and carries vitreous and gray sulphuret ores with carbonates. These have been opened to some extent, and assays show the presence of silver also, in small quantity.

At Blandford cove in Lunenburg county, Mr. Poole, 1862, reports the presence of copper pyrite in slates, as also at Hillsboro brook, Westfield brook, Geysers hill, and Jebogue point. It is also reported as occurring frequently in the gold-bearing lodes of the province.

## NEW BRUNSWICK.

The conditions relating to the occurrence of copper in this province, are somewhat similar to those already described for Nova Scotia. The principal known deposits, may be classed under four heads, viz:

1. Those in connection with pre-Cambrian rocks, comprising schists, felsites, &c. as seen in the mines opened at several points along the north side of the Bay of Fundy, in St. John and Albert counties;

Copper ores in New Brunswick.

2. Those associated with masses of eruptive rocks which cut strata of Silurian and Devonian age, as in southern Charlotte county, in Letite, Adams and Simpson islands, etc.;

Mode of occurrence.

3. As gray copper ore thrown down by the agency of plant remains in sandstone and conglomerate of Carboniferous age, as at Bathurst in Gloucester county, and near Dorchester in Westmoreland county;

4. In trap rocks, of supposed Triassic age, found chiefly on the west side of the Island of Grand Manan; the igneous rocks of that area, being regarded as contemporaneous with those of the North Mountain range, in Nova Scotia.

Early reports.

Reference was made to some of these occurrences by the earliest writers on the geology of the province, including Gesner, Hind and Dr. Robb, of the University of New Brunswick, and later, by Mr. C. Robb and Messrs. Bailey and Matthew, as well as others, engaged in the work of the Geological Survey. As in Nova Scotia, large amounts of capital have been spent from time to time in the attempt to bring certain of these deposits to a state of economic production, but up to the present, these efforts have not been attended with much profit to the investors.

Gesner in his first report, 1839, on the geology of the province, notes the presence of several veins of sulphuret and copper pyrite, with a thickness of two to four inches, as occurring on the shores of Passamaquoddy bay, near the mouth of Digdequash river, the percentage of copper being high, but the extent too limited to be of economic importance. In his second report, 1840, he also refers to the work of the Gloucester Mining Association, as attempting to develop certain occurrences of copper ore in Gloucester county, and also to the presence of ores, comprising sulphurets and carbonates, which were observed along the road, between St. John and Quaco.

Ores of Gloucester county.

In the report of Dr. L. W. Bailey, 1863-64, on the 'Mines and Minerals of New Brunswick', the presence of copper ores is recorded at many points in the province. Among these may be mentioned the deposit at Bathurst, which occurs in the sandstone of the Bonaventure formation, in the form of carbonate, thrown down from solution by the agency of plant stems, which have in part been changed to lignite. This deposit was mined for a short time, till the plant bed was exhausted, when the locality was abandoned. This is probably the first attempt at copper mining in the province. In its mode of occurrence, the ore resembles that found in the Carboniferous of northern Nova Scotia. Attention was also directed in this report, to the presence of copper and manganese, at or near the Falls of the Tête à

Gauche river in Gloucester county, which was opened by a mining company, and a small mining and crushing plant erected for the extraction of these ores. The rocks are reddish and grayish slates, often charged with nodules of manganese, while blocks of good copper ore were scattered over the surface. The enterprise was, however, shortly afterwards abandoned.

Charlotte county.

In Charlotte county, several mines were long ago opened in the Letite peninsula, including those known as the Letite copper mine and the Wheal Louisiana. These were among the first attempts made at mining in this part of the province; and although a considerable amount of money was spent in sinking shafts and driving levels, the results obtained were such as to cause the abandonment of the enterprise. Indications of copper with galena were also seen on the west side of Campobello island, but these deposits have never warranted the expenditure of much capital in their development.

St. John and Albert counties.

In the eastern part of the province, along the Bay of Fundy, Bailey, in the report just mentioned, records the presence of mixed copper ores at certain points, a short distance west of upper Salmon river, in Albert county, worked many years ago by the Williams Mining company, and by the Alma company; and to the Vernon Copper mine, on the shore of the bay, a few miles east of Martin head, opened by the St. John and Albert Mining company. Here chalcopyrite, peacock ore, and gray sulphide, occur in quartz veins, which traverse schists with intrusive diorites and other igneous rocks, and were mined quite extensively for a time, with very poor results. Indications of copper were also observed in this area, at Black river, as copper pyrites; at Goose river, as erubescite; at Little Salmon river, as native copper; at Martin head as chalcopyrite, and at West Beach.

Carleton county.

In Carleton county, chalcopyrite was found at Bulls creek, a few miles south of the town of Woodstock, which was developed to some extent. In Kings county small quantities of copper pyrites were seen at several points, and in addition to the localities already mentioned in Charlotte county, its presence was reported at Adams, Simpson, Deer and Hardwood islands; at the entrance to Magaguadavic river; Moore's mills; St. David and St. Stephen. Most of these have been shown to be of but little value, while some were opened up and mined at intervals for some years.

The above list of localities shows that even at this early date the work of exploration had disclosed the presence of these ores at a number of widely separated points.

Report of Prof. H. Y. Hind.

Professor H. Y. Hind, in his extended report on the geology of the province, 1865, gives quite full details as to the working of several of the deposits mentioned, more especially as relating to the Vernon mine on the upper part of the Bay of Fundy. He also alludes to the presence of copper-bearing traps in this vicinity, which have recently been opened up by an American company, and in the northern part of the province gives further information relating to the ores found at Bathurst, Tetcàgauche; Campbell river on the Tobique where traces of the mineral were found in masses of igneous rock of that area; and to the ores of Bulls creek near Woodstock; as well as to the mines in the Letite peninsula.

The Letite mine.

In the last named place, he describes the rocks as altered slates, often schistose, cut by numerous masses and dykes of diorite, and other igneous rocks. The copper is found unusually near the contact of the intrusives with the altered rock in the form of chalcopyrite with iron pyrites and some native copper in the mass, described by Hind as following a line of fissure, holding calcspar, quartz and bitter-spar. Some of the schists are talcose and magnesian. Although opened by several shafts to a depth of over 100 feet and by tunnels driven off from these along the line of the supposed break, the quality of the ore did not seem to improve over the surface conditions, and work was abandoned.

The Vernon mine.

Of the Vernon mines, Hind gives lengthy descriptions of the several veins and the mode of occurrence of the ore. He held that this was derived from masses of trap which intersect the schists of the area, and that the ores themselves were deposited in fissures as veins, the filling matter being calcite, bitter-spar and quartz. Chlorite is also found in some parts of the deposit. The place of working is in the side of a cliff facing the bay, difficult of access and with no facilities for shipment of the ores after mining. While some good ore was found in the veins, the quantity taken out was not sufficient to pay for the extraction, and this fact, together with the absence of conveniences for shipping, led to the abandonment of the area after the expenditure of a considerable amount of capital in development work. This area has again recently been opened up, but the details of work done have not come to hand.

In the report by Bailey and Matthew, 1870–71, a list is given of all known occurrences in the southern part of the province at that date. Of many of these, it may be here stated that they apparently possess no economic value, but are of interest merely as occurrences of

the ore under certain conditions. In addition to those already mentioned in previous pages are the following:—

*West of St. John, along the shore of the Bay of Fundy.*

Seely cove, copper pyrite (chalcopyrite) in chloritic and felspathic rock; quantity small. Locations north shore of Bay of Fundy.

Seely cove, copper pyrite in chloritic and felspathic rocks.

Seely head, copper pyrite in red syenite and felspathic rocks.

Seely creek, copper pyrite in quartz veins in felspathic rocks.

Shore west of Crow harbour, copper pyrite and glance in quartz veins, cutting chloritic and felspathic rocks.

Cove of Red head, copper and iron pyrite disseminated in schist but no lode.

McLean's mills, New river, copper pyrite in quartz veins.

Negro harbour, copper pyrite.

Beaver harbour, copper pyrite in quartz veins in schistose diorite and with galena in chloritic and felspathic rocks.

Clarkes point, Mascarene, native and gray copper in trap with the reddish slates of this area.

Wheal Louisiana and Letite mines, copper pyrite and erubescite with diorite cutting hard slates. Passamaquoddy Bay mine.

Hardwood island, purple copper in strings and bunches in green chlorite slates.

Adams island, purple copper, veins in calcspar and quartz, with diorites, slates, &c.

Simpson island, copper glance and malachite with trap rocks and slates.

Campo Bello island, near Welshpool, copper and iron pyrite, with galena and blende in hornblende and slaty rocks.

Grand Manan, native copper and copper-glance in trap rocks.

*In St. John county, east of St. John city.*

Black River settlement, copper pyrite and malachite in hard clay slate with plant remains.

Bay of Fundy shore, east of St. John.

Little Salmon river, copper pyrite with iron pyrite in small quantity in slates.

Near Martin head, erubescite in schists.

Vernon mine, near Goose creek, erubescite, malachite, copper pyrite and cuprite in veins or fahl-bands with diorite, purple and gray mica slates, grits and conglomerate.

Point Wolf to Salmon river, erubescite and other ores, probably similar to those of Vernon mine.

Salmon river, 3 miles up from mouth, variegated and copper pyrite in dark slaty grits.

Blackwood block, malachite in hard gray slates.

*Areas inland.*

Beech hill, Westmorland county, copper glance in quartz veins, with fluor spar.

Kings Co. areas.

Quispamsis, Kings county, copper pyrite, with blende and galena in gray chloritic gneiss.

Springfield, Scotch settlement, copper pyrite and glance in pale gray argillite.

London settlement, Kings county, copper pyrite in rusty-weathering sandstone.

McKenzies or Nerepis station, Westfield, copper pyrite with galena and iron pyrite in purple slates.

With the exception of the areas at Vernon mine and upper Salmon river, apparently no attempt has been made to develop these deposits, the economic value of which may be stated as small.

Simpsons island.

Since the date of this last report some mining has been done at various points. In Passamaquoddy bay attempts have been made by several parties to locate the ore seen in a small vein on the beach, at Simpsons island, by sinking a shaft inland and driving towards it, so as to avoid the water which prevented mining operations at the earlier period. So far, these efforts have not been successful in finding any workable ore-body, though small irregular veins have been cut. The ore is of high grade, and when worked at the beach vein it is reported that 60 to 70 bbls. were extracted by Messrs. Lord and Dakin. The influx of water from the tides interfered so greatly with the progress of the work that it had to be abandoned. The last work at this place was about the year 1890, according to Bailey's Report (1897, Vol. VII.)

In the altered slates of Letite about three-fourths of a mile north of the post-office near the road to Back bay, recent attempts have been made to mine a deposit of copper similar to that of the old Letite mine. A shaft has been sunk to a depth of 140 feet in diorite near the contact with altered slates, the ore being a mixture of chalcopyrite with iron pyrite. As the shaft was filled with water during our visit in 1903, it was impossible to learn anything as to the actual copper contents on the spot, but there is no reason to doubt its similarity to those already mined and abandoned in the vicinity, and from the evidence obtainable the conditions are practically the same. The ore body does not appear to be sufficiently extensive to warrant expensive development. From our examinations of the district it would seem that the slates of the locality are of upper Silurian age since well defined fossils of that horizon are found at a number of places, and the alteration to pre-Cambrian looking schists is merely a local one and caused by intrusions of diorite and granite which have also been altered in places to green chloritic schists by the pressure which has affected all the rocks of this area. In fact it would appear that all the mineral occurrences of this district are due to the great period of igneous activity which affected the Passamaquoddy region. While traces of copper are found at a number of points in these altered rocks, at no point does there appear to be any largely developed ore-bodies throughout the area.

Letite mine.

About 1880 attention was directed to the presence of copper in the rocks of the ridge north of Dorchester. The formation includes sandstones and conglomerates of Millstone grit age which form a cliffy front of considerable elevation, resting upon red Lower Carboniferous marls or shales. In the lower part of the sandstone beds remains of plant stems are abundant, and a zone of these can be traced for a long distance following the face of the ridge. Where these remains are found copper has been thrown down from solution and parts of the plants are changed to lignite. The sandstone adjacent to the principal copper deposits is also charged with gray ore to some extent, portions of it containing from a half to three per cent in a fine state of division.

The Dorchester Copper mine.

Attempts to mine these ores were made about 20 years ago and the property was opened by a series of adits along the dip of the beds on which the ores were deposited. In places the showing is very good and a considerable amount of rich ore has been extracted. A shaft was sunk in 1884 to a depth of about 100 feet, when it reached the underlying red marls. Owing to the impossibility at that time of successfully ex-

tracting the disseminated ores by any known process, the property was abandoned. About three years ago another company began development work at this place and erected a large plant for the extraction of the copper by the electrolytic method. The rock was finely crushed and afterwards treated with sulphuric acid, the metal being then thrown down on metal plates as pure copper. While the extraction of the metal was successfully accomplished, the expense of its treatment was such as to preclude the possibility of any profits by this method and the work has again been abandoned. This deposit was first referred to in the Report for 1877-78, p. 120 D.

Indications of copper in nodules are found at several points along the shore below Dorchester on the west side of the Marangouin peninsula in the Lower Carboniferous rocks, under similar conditions to those just mentioned, but these are too small to be of any economic value. These ores are also found at a number of points between Dorchester and Sackville but, in so far as can be learned, will not repay the cost of extraction. Their occurrences are similar to those along the south side of Northumberland strait in Nova Scotia, already described.

General character of the ores.

On the whole, therefore, it may be said from a careful study of the New Brunswick ores that there is a marked resemblance to those of the adjacent province of Nova Scotia, both in the modes of occurrence and in their geological positions. The deposits of copper pyrites, associated often with blende and galena, are almost identical in character and associated rocks with those found in Cape Breton, and are too small in extent and too uncertain in their occurrence to warrant the expenditure of much capital in their development. Those of Passamaquoddy bay and Letite are similar to the ores of Antigonish county and like them have led to the expenditure of large sums in the difficult task of making them remunerative. The Carboniferous ores are practically the same for both provinces, and the expectation of finding large and valuable deposits has not yet been realized; while the attempt to mine the native copper of Grand Manan island, similar in most respects to that of the North Mountain range of the Bay of Fundy, has long since been abandoned. The latest attempt to mine the ores of the igneous rocks of eastern St. John county, which are in spots rich in copper is as yet in the development stage only, and but little can therefore be said as to the true value of this locality.

## QUEBEC.

The copper ores of Quebec are of a somewhat different class from those already described for the eastern provinces. In their mode of occurrence they are usually associated with intrusive rocks, but these occur with older formations and are practically confined to the Pre-Cambrian, probably Huronian, series and to certain parts of the Cambrian system, more especially to that portion which has been described under the head of the " Sillery formation." Copper ores of Quebec.

The occurrences of these ores were given in considerable detail in the report " on Mineral Resources of Quebec " 1888-89, by the writer, and though some development work has been carried on since that date, sometimes by re-opening mines there described and which have been closed for some years, and partly through the discovery of new localities at widely separated points, the general statement as there given cannot be greatly changed. Recent work by Professor Dresser, who has recently been investigating the copper-bearing rocks of the Eastern Townships, has furnished new light as regards the origin of certain of the copper belts from the petrological stand point, and shown that in some cases rocks which were at one time regarded as altered sediments are apparently rather altered eruptives to which a bedded aspect has been imparted by pressure or other agencies. In addition also to the statement given in the report of 1888-89 that these ores were referable to three principal belts, Mr. Dresser has indicated a fourth belt which comprises the ridge of crystalline rocks along and near the boundary between this province and the State of Maine. At the time of writing the report in question however the presence of ore-bodies was pointed out at several localities in this district, more especially with regard to the presence of galena and pyrites ores, so that the later discoveries, which will be referred to again, are to some extent due to the settlement of the country whereby greater facilities for examination have been presented.

In view of these facts the remarks on these ores contained in " Mineral Resources of Quebec, 1888-89 " are quite as applicable at the present time as they were at the date when written, and they may be here introduced with the addition of such matter pertaining to the subject as may have developed since that time. Report on Mineral Resources 1888-89.

While we have seen that the presence of iron ores in workable quantities was known in eastern Canada more than two hundred years ago, and that they have been utilized for nearly a century and a half in the manufacture of iron, the first reference to deposits of copper

First discoveries, Geol. Sur. Rep. 1847-48.

ores in the province of Quebec is apparently that contained in the report of the Geological Survey, 1847-48, where, on pages 26-27, the occurrence of copper pyrites is noted in connection with the limestones of Acton, Upton and Wickham, and further north in Inverness. Reference was however, made in 1830 by Gen. Baddeley, R. E., to the copper ores of western Ontario, but at this date it does not appear that anything was known in relation to those of Quebec. As regards the deposits observed in Quebec, and referred to by Sir William Logan in the report just mentioned, the quantity was generally regarded at that time as unimportant; but several localities were recommended for trial. Among these was a quartz vein on lot four, range two, of Inverness, having a thickness of about two feet, with a course a little north of east, which, however, upon testing, (although the quality of the ore was excellent), did not appear to contain sufficient to render its further exploration profitable.

Ores of Ascot and Upton.

A second area recommended for trial at the same time was the seventeenth lot, seventh range of Ascot. about one mile from Sherbrooke, on the road to Lennoxville. The thickness of the quartz vein here carrying copper pyrites was from ten to twelve inches, cutting chloritic and talcose slates, and it carried, in addition to the copper ore, small quantities of gold and silver. The third locality recommended was in the fifty-first lot of the twenty-first range of Upton; the breadth of the lode, which is in a whitish gray massive limestone, being from twelve to eighteen inches, consisting of white quartz and calcspar, carrying pyrites also in small quantity. Assays of the ores from these three localities were made by Dr. Hunt. The percentage of metallic copper in the washed chalcopyrite from Ascot was 30·34, or eighteen per cent. of the vein; from Inverness, 34·93, or seven per cent. of the unwashed ore, and from the Upton lode, from an average sample, 3·84 per cent.

Geol. Sur. Rep. 1849-50.

In the report of 1849-50, reference was made to traces of copper in the rocks of the Chaudière river, in the seigniory of St. Joseph, where in rear of the church at that place, spots of vitreous copper were found disseminated through quartz veins in red and green slate, and again at about one mile from this river on the road to Frampton. Similar ore, in quartz veins in the red slates, was also at the same time noted as occurring in Ste. Mary's seigniory; but neither of these localities appeared to possess any special value. The deposit at Upton was opened up and found to consist of a series of bunches, following a bend in the stratification; but the opinion was expressed that their irregularity was such as to seriously interfere with their being successfully worked for copper.

The copper deposits of the eastern townships appear to have been entirely neglected for some years after this, but some examinations made about this time on the north side of the St. Lawrence, in the augmentation of Lanoraie and Dautraye, on the left bank of the L'Assomption river, showed the presence of a vein nine inches thick of ccal and pearl-spar, cutting gneiss, which carried copper and iron pyrites. On either side of the main vein, other veins were reported of an inch or more in thickness, also carrying copper pyrites, and the whole group was comprised in a breadth of about nine feet. In this a shaft was sunk for sixteen feet, the veins, which had the aspect of regular lodes, appearing uniform throughout, though the quantity of copper they contained did not seem to be remarkably promising.

Areas North of the St. Lawrence.

A more detailed description of the Upton deposit appeared in the report for 1858. It is there stated to occur in a mass of grayish-white, sometimes reddish-gray limestone, compact sub-crystalline and yellowish-weathering, reticulated by small veins of copper pyrites, as well as by others of quartz and various ores of iron, all of which were regarded as of a segregated origin. This ore-bearing limestone was overlaid by a bed of breccia, or conglomerate, which also carried pyrites and was supposed to be underlaid by reddish-gray limestone, which, towards the bottom, became interstratified with red slates. No copper was found in the underlying limestone. The general dip of the measures was to the south-east at angles of 10° to 27°. The bands of limestone, carrying ore, extend through the northern part of Acton into Wickham where, also, on the twenty-sixth lot of the last range of that township, they also carry similar ores. A second band to the south-east is seen at Acton on lot thirty-two of the third range, which extends approximately parallel to that just mentioned, and also at Wickham, and this was regarded as the equivalent of the Upton bands of rock coming to the surface on the south side of the synclinal.

The Upton mines.

The description of the rocks of this copper belt is considered of some importance, as illustrating a peculiar series, in which has occurred, more particularly at Acton, and presently to be described, one of the most productive copper mines ever worked in Quebec; a band entirely distinct in character from those which contain the copper deposits now so extensively worked in the eastern townships. In order that the relations of the several ore belts may be better understood, we may here proceed to describe, before taking up the history of the several copper mines, which nearly thirty years ago were so prominently before the mining public, the views of structure of the several areas of cupriferous rocks, as stated in the Geology of Canada, in 1863 and 1866, more

especially since the new views of the structure and of the age of these rocks, as stated in the more recent reports, have modified the opinions there expressed to a very considerable extent.

The metamorphic rocks of eastern Quebec were, for many years, regarded as the altered equivalents of the fossiliferous and comparatively unaltered sediments of the St. Lawrence basin; and these were divided at first into two and subsequently by sub-division into three portions, viz.: The Levis, Lauzon and Sillery formations.

Character of the copper-bearing rocks.

These were supposed to be arranged in a series of long and sometimes narrow folds, with many overturn dips, of which it was remarked that "the latter circumstance renders it difficult to determine which of these folds are synclinal and which anticlinal, inasmuch as the outcrop in both cases presents a similar arrangement." These metamorphic rocks, for the portion north of the Vermont boundary, considered to be specially cupriferous, were held to occur in three approximately parallel bands or areas. Thus the first area, or the most westerly, extended from Farnham, near Missisquoi bay, to the

Three areas.

seigniory of Lauzon, on the St. Lawrence. Where it is traversed by the St. Francis river it was supposed to be nearly, or quite, separated into two parts by the appearance of what was then regarded as the underlying series of slates. In this supposed synclinal are found the deposits of Upton, Acton, Wickham, Roxton and Durham, while in the north-eastern extension are those of Wendover, Somerset, Nelson and St. Flavien. The second area, which was supposed to be divided into two parts by the ridge of the Sutton mountain, extended from St. Armand to the seigniory of Ste. Mary, on the Chaudière. In this were the copper deposits of the townships of Sutton, Stukely, Melbourne, Cleveland, Shipton, and further to the north-east those of Halifax, Leeds, Inverness and Ste. Mary.

The western portion of this supposed synclinal occupied the Sutton valley; the eastern, the Potton and Bolton area along the valley of the Missisquoi river. The third area extends from Owls head on Lake Memphremagog to the township of Ham, and included the Stoke mountain, while further to the north-east, it was traced across the Chaudière into Buckland. It was supposed to be separated from the last by what were regarded for the most part as newer rocks, much of which were supposed to be of Upper Silurian age, although now known to belong, in great part, to much older horizons. In this area were included the deposits of Ascot, Ham and Garthby.

The rocks of the first or most westerly area, extending from Farnham north-easterly, were regarded as belonging to the Lauzon

and Sillery divisions of the Quebec group. They include slates, black, red, green and gray, with sandstones, diorites and dolomitic limestones; which are seen at many points. The outcrops at Upton and Acton appear to be very similar in character, and probably represent portions of the same series, brought to the surface by synclinal structure. Of the second main synclinal, as then considered, viz., that in which the Sutton mountain was supposed to occur, the rocks vary somewhat on either side of the mountain ridge; those on the west being, for the most part, schistose and crystalline, either talcose, micaceous or chloritic; while on the east side there is a large development of serpentines, diorites, slates and hard quartzite. The rocks which were found in the third area, or that of Ascot, were also largely schistose, resembling rather those of the western side of the Sutton mountain than of the eastern. It will be seen, therefore, that there is a manifest difference in character of the rocks in the three areas, and by a careful examination of the copper ore obtained from each of these, a corresponding difference in their character will also be observed; the ore of the Ascot belt being unlike that from the Potton area, while this in turn is of a different character from that of Acton or Inverness and Leeds.

Rock of the first or most westerly area.

The studies made of these several groups of strata during the past ten or fifteen years have led to an entire change of opinion regarding their relative ages and structure from that expressed in the Geology of Canada, 1863. Instead of now regarding these different copper-bearing belts as synclinals in the Sillery or other divisions of the Quebec group, and all of Lower Silurian age, it is now very clearly established that while the rocks of the first area are, in large part, of the same age and character as those which have been described as the Sillery formation, and which is now held to form the lowest member of the fossiliferous Quebec group, as developed along the south side of the St. Lawrence river, those of the second and third areas, or of Sutton and Ascot, belong, for the most part at least, to the pre-Cambrian horizon; while the slates and serpentinous or dioritic portions may probably, with more propriety, be classed in the lower portion of the Cambrian system, the slate rocks of which flank the pre-Cambrian schists on either side, and that the greater part at least of these crystalline schists really occur as anticlinal axes instead of as synclinals of altered Lower or Middle Silurian rocks.

Change of view as to age of the rocks.

As just stated, the characters of the ores in the different copper-bearing belts,—for it is scarcely necessary to maintain the use of the term synclinal in view of the change of opinion expressed—varies greatly

Ores of the first belt.

when contrasted. Thus, from the more westerly belt, the ores are largely yellow sulphides, though occasionally varied sulphides are found, mostly in a dolomitic limestone. In the township of Roxton the principal deposit was on lot twenty-three, range three, where the ore, according to the late Mr. Charles Robb, M. E., who had great experience in the mines of this section of Quebec, appeared to be disseminated through a band of this rock for a breadth of fifty feet, but was more particularly concentrated into a breadth of about one foot near a band of diorite. From the west half of this lot, belonging to Lord Aylmer, there had been obtained in January 1864, fifty-six tons of three and a half per cent. ore, sixteen tons of five per cent. and two tons of twelve per cent. ore; and from the eastern half, eight tons of eight per cent. and fourteen of three and a half per cent. were taken. In the adjoining township of Ely, though indications of ore are found at a number of points, the principal deposit was on lots nine and ten of the second range, owned by the Ely Copper Mining Co., where the ores were the yellow and variegated sulphides in a crystalline limestone. In Upton, mining was carried on at four places, viz. 1st, on lot forty-nine of range twenty, called the Bissonette mine, where there was a yellow sulphides in a thickness of three feet and a half of dolomite, yielding from 10 to 15 cwts. of 10 per cent. ore per fathom. 2nd, at the Prince of Wales mine on lot fifty-one of the same range, (the ore being scattered through about twenty feet of the same band as the last) from which about forty tons of twelve and a half per cent. ore were obtained from open cuttings. 3rd, on lot forty-nine, range twenty-one; the ore and rock being similar to the last, and owned by Col. McDougall, by whom, from open cuttings also, about twelve tons of twenty per cent. ore and eight tons of twelve per cent. were obtained; and 4th, the Upton mine, on lots fifty and fifty-one of the same range, where two shafts were sunk to depths of forty-two and twenty-five feet respectively, which yielded a considerable quantity of ore, the exact amount, however, not being stated.

In the township of Acton several mines were located and worked to some extent about this time, but of all these, the one known as the Acton mine, situated on the thirty-second lot of range three, and about half a mile south of Acton station on the Grand Trunk railway, was the most important.

The Acton mine.

The discovery of this mine is said to have been made by Mr. H. P. Merrill, but the date of this discovery is not mentioned. In a paper by Mr. Robert Williams, for many years connected with copper mining in eastern Quebec, read before the Lit. and Hist. Soc. of Quebec, 1865, we learn that in the autumn of 1858, operations were com-

menced by Mr. Sleeper; and 'that although the discovery of copper ore of very rich quality was known some years previously, so incredulous appeared the human mind on the subject, that the property was purchased by Messrs. Davis and Duncan, of Montreal, from the owner, Mr. Cushing, of Actonvale, for a very insignificant sum and a royalty, but these gentlemen had so little faith in their purchase, that they at once leased it to Mr. Sleeper on tribute, at two-thirds of all the ore that he could obtain from it for a period of three years.'

It was largely in consequence, apparently, of the good results obtained by Mr. Sleeper at this mine, that the great boom in copper mining and exploration took place in the townships, which resulted in the finding of the ore in greater or less quantity at hundreds of places throughout the areas already outlined, and of which a full list of localities will be found in the report of the Geological Survey for 1866, prepared by Mr. James Richardson.

Mode of occurrence of the ore.

The peculiar character of the deposit at this place, and the great importance which for some years attached to this mine renders it worthy of a somewhat detailed description. When first found 'the surface presented an accumulation of blocks of copper ore, evidently in place, and covering an area of about sixteen paces in length by ten in width. These masses consisted of variegated sulphuret of copper, intermingled with limestone and a siliceous matter, without anything like veinstone, and evidently constituted a bed, subordinate to the limestone, whose strike was about north-east, and with a dip to north-west at an angle of about forty degrees. In continuation of this bed, for about seventy paces in either direction, the limestone was observed to hold little patches and seams of variegated ore and yellow pyrites, with stains of the blue and green carbonates of copper. The limestones in the immediate vicinity presented several veins of quartz crossing the strike, but containing only traces of copper.'*

The mine was worked by Mr. Sleeper to September, 1861, when it reverted to the proprietors, Messrs. Davis and Duncan, of Montreal, by whom it was sold, in October, 1862, to the Southeastern Mining Company of Canada. The enormous masses of rich ore-bearing rock gradually became exhausted, though no attempt at any very deep exploratory works appears to have been undertaken. According to Mr. Richardson's notes, the mine produced, during the period in which it was worked, 16,300 tons of 12 per cent. ore, sent to market, besides a great amount of a lower grade left at the surface.†

* Report Geol, Survey, 1858, pp. 57, 58. † Report Geol. Survey, 1866.

Mr. Thos. Macfarlane's views.

The ore at this mine, from a number of sections furnished by Mr. Thos. Macfarlane, who was in charge of operations there for some time, and who published an exhaustive paper on the subject in the Can. Nat., 1863, is apparently for the most part confined to a bed of dolomitic limestone interstratified with dark gray shales, a considerable thickness of which lies between the copper limestone and a great mass of another limestone band, which forms a prominent ridge to the south of the workings. Between the copper limestone and the shale beneath, intrusions occur, often of considerable size, of a greenish fine-grained diorite, which are also at times found above the limestone band. The strata, both above and below the limestone band, also contain small strings of copper pyrites, but the workable deposits are for the most part confined to the calcareous portion. The cupriferous rocks appear to be bent in an anticlinal fold, and are, to some extent, affected by faults; these being probably due to the diorite intrusions.

Ore in limestone associated with diorite.

The bed of limestone, which appears to have carried the bulk of the ore, appeared in places as a solid mass, at others as a brecciated rock or a conglomerate; the latter consisted of the pyritous, the variegated and the vitreous ores disseminated through the brecciated bed, constituting, to some extent, with silica, the paste of the mass. The ore deposit at Upton presents a somewhat similar set of conditions, with this important difference that, while at Acton the prevailing ores were vitreous and variegated, at Upton the ore was mostly chalcopyrite.

If the two localities of Upton and Acton should be the outcrop of the same beds on the two sides of a synclinal, it is very possible that other large deposits of similar ores may occur besides those already worked. To test this point at Acton would, however, require considerable expense for shafting. Several bore-holes have been put down, but the results obtained have not been made available. From the fact that red slates of the Sillery formation cross the Grand Trunk railway a short distance east of this mine, and appear, also, near the village of Acton, as well as in the lower beds of Upton, it is probable, that the unusual development of copper is in rocks of Sillery age, and that its presence is here due to the intrusion of dioritic matter since at other localities in this formation, as at Nelson, St. Apollinaire, &c., though the amount of copper is not so large as at Acton, the presence of diorite masses at these places, in somewhat similar rocks, has apparently produced similar effects, though on a much more limited scale.

Among other localities in Acton township where exploratory work was carried on about this time, were lot thirty-one, range four, called the Vale mine, the results from which were of little value: and the White Horse mine on lot twenty-nine of range six, and on lot thirty-one of range three, the ores being similar to those of the Acton mine, and, as at that place, occurring in dolomite. It is probable that the diorites were absent from these localities, no mention being made of them at either place. In Wendover, in the diorites which cross the St. Francis from the town of Drummondville, several shafts from 30 to 40 feet in depth were sunk between 1860 and 1863 by the Drummondvillle Mining Co. of Canada, but without finding copper in any quantity, though just before the suspension of the company a large vein was reported to have been struck. Since the failure of the company no further attempt has been made to ascertain its value. Drummondville mine.

In Wickham two mines were located. The first and most important, was styled the Wickham mine, on lot fourteen, range ten; the ores being yellow and variegated sulphides in dolomite. Here a shaft was sunk to a depth of thirty feet and a few tons of ore removed. The Toomey mine, on the third lot of the eleventh range, was in similar rock of ore, but the work done was merely exploratory and confined entirely to the surface.

In the township of Durham, adjoining Acton, ores of the same character are found. Two mines were here started, of which that on the twenty-first lot of the seventh range, styled the Durham mine was apparently the more important. Shafts were here sunk on three veins, varying from three to twelve inches in thickness, the deepest shaft being eighty-four feet and ending in black slate. The ore obtained amounted to ten tons of five per cent., 110 tons of three per cent., and 300 tons of one per cent., consisting of yellow sulphide in a calcspar vein cutting dolomite. On lot nine, range six, a shaft was also sunk to a depth of sixty-four feet in similar ore, but no returns are given; and on the south-west half of lot nine, range four, a shaft was sunk to a depth of forty feet, showing good specimens of the variegated and yellow sulphides, while a second shaft of sixty feet was sunk on the north-east quarter of the same lot, in green and black slates, for which no returns are available. Mines of Durham.

In Somerset, near the northern portion of this area, small quantities of the yellow sulphides have been observed in beds of limestone conglomerate near diorites; and in Nelson, on lot eight of range eleven, the yellow and variegated ores are disseminated through limestone, also near diorites, from which about ten tons were extracted by a

company formed in Boston. The width of the ore-bearing bed was about thirteen feet. At various points along this line also, indications of ores, for the most part similar to those already described, but presumably in even smaller quantity, were observed. In the county of Lotbinière, near St. Apollinaire, indications of the yellow sulphide are found in amygdaloidal diorite; and in this vicinity the St. Flavien mines were worked about thirty years ago. Since that time no attempt at exploration in any part of this area appears to have been made.

Copper ore associated with diorite.

Throughout the rocks of the western division, the workable deposits of copper also appear in all cases to have been associated with masses of intrusive diorite, which have penetrated the red and green slates and limestones of the Sillery formation, now regarded as forming the upper portion of the Cambrian system. The want of success which has attended many of these workings is due largely to decline in the price of copper, and also to a lack of concentration of the ore in the cupriferous beds, since the quality of much of that obtained is excellent and in some cases peculiarly rich, as seen in the Actonvale deposits.

Mines of the second or middle belt.

Of the mines found in the second belt, beginning at St. Armand, it may be remarked that the ores here observed, differ somewhat both in character and mode of occurrence, and, as already pointed out, in the nature of the containing rock. In this area, at the time of the great copper excitement, several localities were indicated in which traces of the metal, both as sulphides and carbonates, the latter in green chloritic and epidotic rock, were found, but none were at that time shown to be of much importance. In 1882, however, a vein of yellow and variegated ore was opened on the south side of the Pinnacle mountain, St. Armand, in greenish micaceous and chloritic schist, which was worked for some time, and at first promised well. Crushing and concentrating works were erected. and a considerable quantity of the ore extracted and prepared for market, but the works were shortly afterwards abandoned, and no returns from this location are at hand. In the township of Sutton, adjoining, copper mining was carried on at a number of points; indications of the presence of the ore being frequent. These ores were mostly the yellow sulphide, but green carbonate of copper, with deposits of the variegated and vitreous ores, were frequently observed. Among the most important of these in this township, and which have been opened up to some extent, may be mentioned the following:—

Sweet's mine.

Sweet's mine, on the west half of lot eight, range ten, where variegated and vitreous sulphides occur in a bed of nacreous schists from one to four feet and a half wide, which, for the whole breadth,

yielded four and a half per cent, of copper. A band of dolomite occurs in the vicinity, but the ore is confined principally to the schists; differing in this respect from those of the first belt, of which the Acton mine may be taken as the type. This mine was one of the first opened in this portion of Quebec; samples being displayed at the International Exhibition in London, 1862. The schists in which it and the mine on the Pinnacle are located, belong to a distinctly lower geological horizon than that of the belt just described from Farnham, north. A considerable quantity of ore was raised from the Sweet mine, but probably the limited size of the lode interfered with its successful development.

Sutton. The works of the North Sutton Mining Co. were located on the north half of the eleventh lot in the tenth range, on a bed from eight inches to two feet thick, in talcose slate, near black plumbaginous slate. Three shafts were sunk, one of which was twelve feet deep, and about two tons of five per cent ore were obtained. Explorations were also carried on by this company on a seven feet vein in nacreous slates, on the west half of lot twelve, range eleven, carrying yellow sulphide with iron pyrites, but no returns are at hand from this exploration. Two shafts of a depth of fourteen and nineteen feet respectively, were sunk.

On the east half of lot nine, range eleven, the Brome Mining Co. also sank a shaft sixty feet deep on a bed of variegated and vitreous ore in similar nacreous slates, of which it was supposed three feet of the rock would carry three per cent ore. From this also no returns are available, and in the south-east half of lot seven, same range, explorations on a four feet band in chloritic slates yielded, according to Mr. Chas. Robb, a considerable quantity of ore.

Brome. In the adjoining township of Brome, mining was carried on at several points. On the east half of lot five of the fifth range, the yellow and variegated sulphides were found in three bands, varying from two to thirteen feet thick, supposed to be repetitions of one and the same bed through undulations of the strata. Three shafts were here sunk by the Canada Copper Mining Co. to a considerable depth, and a large quantity of ore, estimated to grade three per cent, was extracted. Machinery for crushing and concentrating was erected, but the company soon ceased operations. On lot six, range six, considerable exploratory work was carried on by the Bedford Mining Co., but with no satisfactory result. On the west half of lot twelve, range seven, the Tibbets mine, owned by Messrs. Ball and Morell, consisting of a shaft eighteen feet in depth, was sunk on a band of yellow sulphide

in nacreous and chloritic schist. On lot six, range seven, the variegated ore was found in two bands, one of which, two to three feet thick, was estimated to carry one per cent of copper, the other band of five feet was supposed to carry one and a half per cent ore.

On lot eighteen of range eight variegated and vitreous ores were observed to occur in four bands in nacreous, chloritic and epidotic slates, and dolomite, in a breadth of several yards, and a small excavation, not sufficient for a test, was made. These ores were continued on lot nineteen of the same range, and on lot twenty-one, range nine, but no returns as to value or output from any of these are at hand.

Shefford. In the township of Shefford, mining was carried on at two places only, viz., by the Glencoe Mining Co., on lot seventeen, range two, where the different ores occur with quartz and calcspar in four separate bands in micaceous and chloritic slate, and on lot twenty-eight, range three, by the Waterloo Mining Co., in similar ores, and with similar country rock, where a shaft was sunk to a depth of sixty feet, but no returns are available.

Stukely. Further north in Stukely, the Grand Trunk mine was situated in the south-east quarter of lot six, range one. A shaft was here put down to a depth of sixty feet on a band containing yellow and variegated sulphides, in micaceous and chloritic slates, with dolomite of the usual character. The same bed, with a thickness of three feet, was found on the lot adjoining; some good ore was obtained, but the quantity is unknown. A trial shaft, twenty-one feet deep, was also sunk by Messrs. Lambe and Shepherd in the south half of lot seven, range two, on a band of fifteen to twenty feet of dolomite, carrying disseminated yellow ore with pyrites. On the south-east quarter of lot nine and the south-west quarter of lot ten, range six, vitreous sulphide occurs in chloritic sandstone associated with quartz, feldspar and chlorite; masses of pure ore being obtained weighing from three to twelve pounds. On the latter area the Logan mine was located, in which from four to five tons of twenty per cent ore were obtained.

On lot seven, range eight, two parallel bands of dolomite. carrying vitreous sulphide occur, with a breadth of twenty-three and thirty-six feet respectively, separated by about a hundred and seventy-five yards of micaceous and chloritic slates. The ores are intimately associated with veins and strings of quartz, calcspar, chlorite and epidote. A shaft was sunk for sixty feet and a cross-cut driven twelve feet across toward the vein to the west, but did not reach the ore. On the north-east half of lot six, range nine, a shaft was sunk for one

hundred and forty-two feet in a slate band, carrying similar ore to the last, without satisfactory results, and on the south half of lot four, tenth range, a shaft twenty-two feet deep was sunk in order to cut a band eighty to ninety paces wide, in which four cupriferous bands occur. No returns from any of these are available.

Tracing this belt to the north, we have, in Melbourne, several deposits of copper ore, for the most part in green chloritic rocks and micaceous schists. On these deposits three mines have been in operation, viz., the Ryan Hill, the Cold Spring and the Balrath, The first is situated on lot two, range two; the ore is the variegated and vitreous sulphide in chloritic slates; the size of the band has not being stated. At the Cold Spring mine, lot six, range two, some shafting was done; the ore occurred in narrow bands over a considerable breadth, but presumably not in sufficient quantity to be economicably valuable. At the Balrath mine, on lot two, range four, the ore, which is of the kind just described, is said to occur in a series of bands, eight in number, ranging from one and a half to five feet in width, in one of which a shaft was sunk, which disclosed some rich bunches of ore. Considerable exploratory work was also done on lot eight, range one, in the shape of pits and trial shafts, on a deposit of yellow sulphide; the ore being mixed with magnetic and specular iron, in a gangue of quartz and calcspar, cutting quartzite and talcose slates. None of these areas appear to have yielded very much copper. Melbourne.

In Cleveland, across the St. Francis river, variegated and vitreous ores also occur, with similar chloritic rocks, at a number of places. The only locations worked to any extent, however, were on lot twenty-five, range twelve, at the St. Francis mine, and at the Jackson mine, on the south-west quarter of lot twenty-six of range thirteen. At the former place, in addition to the usual ores already mentioned, green and blue carbonates are said to occur with a little native copper; the whole contained in a lode three feet thick. A shaft was here sunk for 195 feet, and levels and other works driven for 513 feet along the lode, from which a large quantity of ore was taken, which, according to Mr. Bennett, the manager, ranged from six to twenty-six per cent. At the Jackson mine a shaft was sunk to a depth of twenty feet, the ore being found in a lode one foot in width, with other veins carrying ore in smaller quantity at no great distance from it. The amount of ore extracted from either of these places is not known. Cleveland.

In Shipton, copper ores are comparatively rare, at least in so far as known, and not in sufficient quantity apparently to warrant mining operations; but in Halifax the variegated and vitreous ores are again Shipton.

quite extensively distributed, the rocks being schists of the same character as in Melbourne. Mining was carried on at two places, viz., by the Halifax Mining Co., on lot ten of range three, where a considerable admixture of different ores was found in a vein from eight inches to three feet in width, on what is known as the Halifax mine, and visible gold was reported in a quartz vein which was cut. Considerable work was done here by shafts and adits, but no returns as to the amount of ore obtained are at hand, though no large bodies of it were found. At the Black Lake mine, on lot nine, range nine, some exploratory work was also done by Dr. James Reed and others, but nothing of importance was encountered.

Chester. In Chester, although exploratory work was carried on at a number of points, the most important location probably was that in the S. E. half of lot eight, range six, known as the Viger mine. Here the ore was principally the yellow sulphide in quartz veins, and vitreous ore in the slates. The veins were scattered through a width of 170 feet and were opened at a number of points, from which a considerable quantity of ore was extracted, but involving a large outlay and much work. No deposits of large size were met with, and the explorations, after a very thorough trial, were found to be unprofitable. The metalliferous veins on this property extend across into the adjoining lot, but their size was insufficient to pay for the labor involved in the opening. On lot nineteen, range ten, the Austin Mining Co., made a couple of openings, one on a two-feet vein, the other on one of six feet, but the ores were found to be not sufficiently concentrated in the gangue to pay for extraction. Explorations were also made on lots eleven and fourteen of Craigs Road range, in variegated and vitreous ores in limestone, but without success, as well as on lot five, range six, where a quartz vein from two to four feet thick was observed, which presented some good specimens of ore, but the quantity was too small for successful mining.

Inverness. Ores similar to the last are found at several points in Inverness, occurring in micaceous, chloritic and nacreous slates or schists, but, in so far as known, no attempt at mining them was made, though one of these localities was among the first recommended for trial in 1847. In Leeds, however, in addition to the great Harvey Hill mine, very fully described in the Geol. of Can., 1863, several other deposits were worked, notably that on the fifteenth lot of the fourteenth range, in close proximity to the Harvey Hill deposit, the veins and ore beds from which, were supposed to be continuous in this direction. The ores are all vitreous, variegated and yellow sulphides occurring in beds or

veins, in what have been styled nacreous slates, and, on the lot just mentioned, they were owned by the English and Canadian Mining Co. Native gold was found in one of the ore veins. Not far distant from this, to the north-east, in that part of the seigniory of St. Giles known as the Handkerchief, the Chaudière Mining Co., opened up several quartz veins, of which eight were exposed in a breadth of 1,100 feet, two of which had a thickness of two to three feet, and could be traced for 1,200 to 1,500 feet. About $5,000 were spent in these explorations, but owing to difficulties of various kinds, the work was shortly abandoned. Fine specimens of ore were obtained here, and the quartz is reported by Dr. Reed to have yielded him native and visible gold.

What was regarded as the eastern limit of the second belt was the seigniory of St. Mary, where ores similar to those just described occur in red and green slates near ferruginous dolomite, not far from St. Mary's church. From the aspect of the strata, it would, however, almost appear as if this deposit should be more closely related to the red slates and dolomite of the first area. Another mine at St. Sylvester, referred to in the report of the Geol. Survey for 1866, was that of St. Margaret. It was opened by the late Thos. Glover of Quebec, by whom a company was formed in New York, styled the St. Margaret Mining Co. Several shafts were sunk with an expenditure of about $5,000, the amount of ore obtained being about fifty tons. The ore was mostly the variegated sulphide, the country rock consisting of purple slates, green grits and quartzites. The mine was owned by Mr. Cromwell, but the ore appeared not to be in sufficient quantity for profitable extraction.

The most important of the mines in this section, is that so widely known as the Harvey Hill, now the Excelsior, on lot seventeen, range fifteen, of Leeds. This location, according to a paper by Mr. Herbert Williams read to the Literary and Historical Society, Quebec, 1865, was the second discovered in the province as carrying copper, the first found having been at Inverness. These discoveries did not appear to awaken very great interest for some time, and Dr. James Douglas seems to be the first who appreciated their value, and through his agency the Megantic Mining Co. was formed for the purpose of exploring and working the copper deposits of Megantic county. Upon the discovery of the Harvey Hill deposit, the location was secured by this gentleman and his associates, who organized a company under the name of the Quebec and St. Francis Mining Co. Little further investigation was, however, undertaken by any others except this company, who explored the Harvey Hill property in

The Harvey Hill mine.

such a way as to bring it prominently to the notice of English capitalists, and by these a new company was formed in 1858, under the name of the English and Canadian Mining Co., by whom operations were commenced and carried on with varying success for a number of years. The history of the workings of this celebrated mine for some years is given in the Geol. of Can., 1863, with considerable detail. From this we learn that the ores occur in two ways, first as a series of interstratified beds, of which three were clearly recognized, varying in thickness from six inches to six feet, or possibly more, and second, in lodes or veins, composed of quartz, with calcite, pearl-spar and chlorite, some of which carried the variegated and vitreous ores; others carried copper pyrites, in places, in very rich pockets. The veins which sometimes cut across the bedding, were exceedingly rich in certain parts, and in others comparatively barren, so much so that in actual value as a source of supply for copper, the beds were considered the more important. In these the various ores were disseminated through the body of the slates, generally in lenticular masses, running with the bedding. These masses were generally small and thin, sometimes having a thickness up to three-fourths of an inch, with a length of six to twelve inches, in addition to scattered grains of the ore through the slate bed; the amount of copper in all being estimated at from three to five per cent.

Early history.

xploration.

The hill upon which this mine is situated was pierced by a number of shafts from twelve to forty-five feet deep, as well as by tunnels and an adit; the whole forming a very extensive series of workings. The principal adit was driven into the hill across the measures for a distance of 1,488 feet and intersected the several ore beds, the upper one of which had a thickness, when first worked, of three feet, which, in the lower workings, increased to ten feet and was estimated to carry five per cent. ore. From a prospectus issued by the Consolidated Copper Co. of Canada, limited, in 1872, the subsequent history of this mine is given to that date. The surface works of the company, including much of the plant, were destroyed by fire in 1866, with an estimated loss of £20,000, owing to which, operations were suspended till 1870, when Dr. James Douglas, one of the proprietors, took over the work again and resumed operations in the mine. The quantity of ore raised from the commencement of operations in 1858, to the end of 1862 was 322 tons containing thirty per cent. copper, in addition to 1,000 tons at the surface of two and a half per cent. and 500 tons of four to five per cent from the upper bed. The figures as to the output for the different years, as given by Mr. H. Williams, the manager, are as follows:—

Output.

| | Tons. | Cwts. | Qtrs. | Lbs. | |
|---|---|---|---|---|---|
| 1858 | 9 | 15 | 0 | 2 | of 30 per cent. copper. |
| 1859 | 43 | 7 | 0 | 21 | |
| 1860 | 104 | 5 | 3 | 0 | |
| 1861 | 70 | 4 | 1 | 6 | |
| 1862 | 94 | 17 | 2 | 21 | |
| 1863 | 113 | 20 | 3 | 14 | of 26 per cent, copper. |
| 1864 | 235 | 12 | 3 | 4 | of 20 per cent. copper. |

The mining ton = 21 cwts., or 2,352 lbs.

The falling off in the value of per centage is attributed to the fact that during the last years the mining was confined principally to the beds and not to the quartz veins. The ore in these beds was found by Mr. Williams, upon careful examination, to occur in lenticular masses, as already stated, varying in thickness from one-sixth of an inch to two or three inches, and in length from three to eighteen and even twenty-four inches. These masses overlapped each other and were disseminated throughout a thickness of five to six feet. This refers to the overlying or upper bed, which appears to have been the one principally worked. For 1865 the figures for the output seem to be wanting, but from the report of Mr. Harrold Douglas, superintendent of the mine, as given in the prospectus of the Consolidated Co. mentioned, it appears that for a part of 1866, in which year the works were destroyed, 265 fathoms of ore were taken from the bed, dressed to twenty-four per cent and sold in Liverpool for $35,420, being an average of fifteen shillings per unit. From a paper by Mr. James Douglas, jr., of Quebec, in the Lit. and Hist. Soc. of that city, 1870, in discussing the several beds from which the supply of ore had been principally derived, he considers that 'there is no likelihood of these beds being of such great extent or of such uniform richness as was at one time attributed to them.'

Character of the ore deposits.

The work of Mr. Williams on the main or upper beds showed that where quartz lodes cut the beds, deposits of ore, often of considerable size and great richness, were struck; that the beds gradually became less rich in copper as they were worked away from the lodes which had all along been supposed to derive their supply of ore from the beds with which they were associated; but certain features observed in driving an inclined shaft on a lode, reached from the Kent shaft, induced a change of belief in this respect, the evidence there presented going to show that the beds derived their supply of copper from the lodes by percolation into the contiguous slates, and subsequent operations appear to have confirmed this view.

The most important probably of the different lodes struck in the several shafts is that known as the "Fanny Eliza." This entered the

Nature of the lodes.

bed near the intersection of the Kent shaft, and on this lode the greatest amount of work appears to have been expended. Where first struck, near the shaft, it was of small size, but rapidly widened as it was opened. Mr. Douglas says of it: 'The lode is from twenty to twenty-four inches in width, and very regular, both in dip and strike, which is slightly to the west. The ore, as it comes to the surface, yields from eight to twelve per cent copper. It separates in crushing, very perfectly from the gangue, and is therefore easily concentrated to from forty to fifty per cent. It consists of a mixture of gray and purple sulphurets. When the lode enters the bed it carries a good deal of yellow and no gray ore, but the yellow entirely disappears in depth. The ore occupies the centre of the lode, whose matrix consists of calcspar, some quartz and a good deal of bitter spar, in the composition of which iron replaces part of the magnesia.'

"Tracing the lode upward, but beneath the bed and beyond the spot where it first attracted attention, it is seen, in the thirty feet cross-cut, as a well defined lode of about eight inches wide, but carrying very little copper, and has been reached by a level driven upon it from the bottom of Kent's shaft, where, however, it is thin and irregular, though highly charged with copper.' From Mr. Douglas's paper we learn, further, that to the east of the Fanny Eliza two lodes enter the bed, on one of which, some work was done. The lode runs parallel with the Fanny Eliza, and like it increases in size in the direction of the dip, but diminishes towards the rise.' He says, also, that 'the beds gradually decrease in richness in proportion to their distance from the lode.' Mr. Douglas also maintains that the Fanny Eliza is a true lode maintaining its width and direction for forty fathoms with a regular dip, and holds that the veins which take their rise in the roof of the bed are also lodes and not lenticular masses. The vicinity of the lodes is indicated by an increase in the richness of the slates and the kind of ore which they carry. These mines, after having been idle for some years, have lately changed hands and are now being worked by the Excelsior Copper Co. From the notes of Mr. C. W. Willimott, who visited the spot in 1882, we learn that the mine closed work in 1879; operations having been confined principally to the Fanny Eliza lode or vein; in the level and incline which had been sunk to a distance of 600 feet, some rich pockets of ore had been found. The mines, in 1882, were owned by a New York company, but no work, other than taking the water out of the shaft, was then going on. The Excelsior Copper Co. had been carrying on work during the preceding two years, but had not extended their underground operations to any great distance, having merely cleared the shafts of water, repaired the timbering and the build-

ings and erected a smelter, in which a considerable quantity of the ore lying about had been reduced, the coke for this purpose having been obtained from Nova Scotia, the limestone from Dudswell, and the iron from McVeity's mine near Kinnears Mills, but no returns of output or of other results are to hand. The manager was Col. Drew Gay. This property again changed hands, and is now owned by Dr. James Reed, by whom some development work was done, though operations have been suspended for several years. The surface plant is now much out of repair.

On lot sixteen, range fourteen, adjoining the Harvey Hill property to the north, the Leeds Mining Co., began operations in 1863. These were carried on for a couple of years, in anticipation of meeting the extension of the rich lodes and beds of the Harvey Hill mine, but in this their expectations were not realized, since the extension of these beds to this property was not found sufficiently rich in copper to pay for mining. These works were suspended in 1865. They were under the general supervision of Mr. Herbert Williams, and no attempt has since been made to further develop the property.

Ores of the second belt.

The second range of mines in what was, in 1863, regarded as the eastern portion of the second synclinal, or that area east of the Sutton Mountain ridge, included those of Potton, Durham, Brome, Bolton, Oxford and Brompton. The rocks here, in places, differ markedly from those of the area just described, being very frequently black and variously colored slates, with great areas of serpentines and diorites, but the characters of the ore are, in some cases, similar to those from the west side of the Sutton ridge, though in certain of the mines, some features which are different will be mentioned.

Potton. Lake Memphremagog.

In the township of Potton, the yellow sulphide is the most abundant ore, the vitreous being rarely found. The rocks here are mostly slates and diorites with serpentines; the copper pyrites is largely mixed with iron pyrite, much of which is the magnetic variety or pyrrhotite. In no case yet observed in this township is the quantity of ore sufficient to warrant any great outlay in exploration, except, possibly, at the recently discovered mine on lot twenty-eight, range nine, on the west side of the Hogs Back mountain, owned by the Memphremagog Mining Co. This mountain is a mass of diorite, rising to a height of about 800 feet above Lake Memphremagog, and surrounded on both sides by black and bluish gray slates. The deposit of ore, which is principally a pyrrhotite with a small quantity of copper pyrites, occurs on the west side, at the contact of the diorite and slates, in a bed fifteen to eighteen feet thick, which extends

along the side of the mountain for several hundred yards. It dips north-west at an angle of about forty degrees, having the diorite for its foot wall, while the surface above the vein and for some distance beyond is covered with a heavy bed of bog iron ore. The copper ore, in situ, contains a considerable quantity of a dark-coloured or almost black calcite. On this vein several pits have been sunk at intervals along a distance of 1,000 feet, and, according to the manager, an inclined shaft has been put down on the vein for eighty-five feet. A cross-cut has also been driven with the vein, so as to drain the pits. About 800 tons of the ore have been extracted and piled, waiting for shipment. From several assays by Dr. Wyatt of New York, and by Torrey and Eton, the ore contains from different samples:—

| | |
|---|---|
| Iron | 30 to 50 per cent. |
| Copper | 2·80 to 5 " |
| Sulphur | 37·25 to 42 " |

A peculiarity of this ore is the readiness with which it spontaneously ignites when piled in heaps exposed to the weather; a feature not common to the ores from most of the other locations.

This mine is situated at 700 feet above the lake, connected by a good road a mile in length with landing-stage, and good facilities for shipment, either to Magog or Newport. Recent developments on this property are mentioned on a subsequent page.

Bolton.

In Bolton, the township adjoining to the north, the extension of the slates and serpentines is found, and mining operations were carried on quite extensively for some years at several points within it. Probably the most important of these was the celebrated Huntington mine, on lot eight, range eight, and the Ives mine, a couple of miles further to the north, on lot two, range nine, and lot four, range eight. In the former, the ores are mostly copper pyrites, mixed with the magnetic pyrites or pyrrhotite, a large deposit of which occurs in chloritic slates in contact with serpentine and diorites. A band of more than three feet of solid granular copper ore occurs near the serpentines on the west side of the vein. A section of the metalliferous portion, going eastward from the western wall of serpentine is as follows:—

Huntington Mine.

| | Feet. |
|---|---|
| * 1. Greenish diorites, with disseminated masses of copper pyrites and magnetic iron pyrites | 2·0 |
| 2. Compact granular copper and iron pyrites with disseminated masses of quartz | 1·4 |
| 3. Magnetic iron pyrites, interstratified with thin leaves of chloritic and mica schist | 0·9 |
| 4. Greenish diorite with disseminated copper and iron pyrites | 1·0 |
| 5. Compact granular iron pyrites, with disseminated small masses of quartz | 2·6 |
| 6. Green chloritic slate, with disseminated masses of copper pyrites, mingled with iron pyrites | 8·0 |
| | 15·7 |

* Geol. Surv. Rep. 1866, p. 35.

Work was begun on this property in August, 1865. From notes kindly furnished me by Capt. W. Warne, the present manager of the Memphremagog Mining Co's. work, the management was in the hands of Capt. Bennett of Lennoxville, who controlled operations till 1870-71, when the mine was sold to a Glasgow company and the name changed to the Huntington Copper and Sulphur Co., under the management of Mr. John Rudda, of Cornwall. The output under the old company's management is stated to have been from 200 to 300 tons of ten per cent ore per month, part of which was shipped to England and part to the United States. Extensive buildings, etc., were erected, and under Capt. Rudda's management, the output was increased to 400 to 500 tons per month of seven per cent ore.

In 1872, works were erected for carrying on the Longmaid or Henderson process, which, however, did not apparently meet with much success. The ore was burnt in retorts to drive off the sulphur, then crushed, mixed with common salt, and calcined in furnaces, placed in vats with hot water and acid from the tower, and run off into other vats containing scrap iron, by which the copper was precipitated. Hundreds of tons of precipitate, containing 65 to 75 per cent of copper, are said to have been made in this way.

In 1873, the works were destroyed by fire with a loss of $75,000. They were partially rebuilt, and mining was carried on in a desultory fashon for several years, and the company finally closed operations in 1883. In 1888 the property passed into the hands of Messrs. G. H. Nichols & Co., of Capelton.

In the working of this mine, two deep shafts were sunk, one to the depth of between 500 and 600 feet, called the Huntington shaft, the other known as the Wright shaft, 200 feet deep. North of the Huntington mine, on lot six, range eight, were the works of the Canadian mine, presumably on an extension of the vein just described. Two shafts were here sunk, one to a depth of 100 feet, the other to 50 feet, and some ore shipped to Capelton. The mine subsequently passed into the hands of the Eastern Townships Bank and has not been worked for some years.

Bolton, Ives mine.

Further north, on lot two, range nine, Bolton, the Ives mine was situated. Two shafts were here sunk, the Ferrier and the Galt, the former to a depth of about sixty feet, the latter to 100 feet. This mine was opened in 1866, and worked for ten years, and a large quantity of from 10 to 14 per cent ore was extracted and shipped to

England. These three mines are situated on the east side of the Missisquoi river, south of what is now known as Eastman, and are all probably located on the same belt of ore. The serpentine rock is found at all these mines, with slates of various colors, differing, in this respect, from the rocks of the second area or that west of the Sutton mountain. Very favourable reports on these deposits have appeared by Dr. T. Sterry Hunt and others, but the presence of the magnetic pyrites serves to distinguish the ores as a class from those already described.

Orford.

The copper deposits of Orford township were mined at several points. On lot nine, range A, yellow sulphide occurs in a dioritic rock, near serpentine, of which six veins are found in twenty-five feet. This was exploited by Messrs. McLeod and others. On the third lot of range F, and on the eighth lot of the same range, similar ores, with a like association of rock matter, were found, but at none of these does systematic mining seem to have been carried on.

Brompton lake.

At the King mine, on the third lot, in range thirteen, variegated ore, associated with magnetic oxide of iron, occurs in a four-feet band of dolomite and serpentine; and on the west side of Brompton lake, on the east side of a high hill, called the Carbuncle, composed of diorite and serpentine, several small openings were made, from which, in all, about twelve tons of twelve per cent ore are said to have been obtained. The difficulties of working this deposit, from its comparative inaccessibility, must have been very great, and the quantity of ore in the rock appears at present very limited, although a five feet vein of solid yellow sulphide is reported to occur there. This mine was styled the Carbuncle Hill mine and was located in the second lot of the fourteenth range of Orford. In the township of Brompton, the only mine worked was on lots twenty-eight and twenty-nine of range nine, where the ores, which were of the variagated and vitreous varieties, were found in serpentine. According to Mr. Chas. Robb, the principal deposit was in a five feet vein, containing, according to his report, a promising quantity of ore. It has, however, long since been abandoned.

Mines of the third area

In what we have styled the third area, viz., that of Ascot and Hatley, we find a great series of deposits which have of late years proved to be among the most valuable in eastern Quebec, not probably so much for the amount of copper contained as for their adaptability to the manufacture of sulphuric acid. In this respect the ores of this most easterly belt differ widely from those of the two areas already described.

Ascot and Hatley.

The variegated and vitreous ores are, for the most part, wanting, the bulk of the ore being a chalcopyrite, with much iron pyrites. The amount of copper contained is not high, averaging, for the great bulk of the production, from four to five per cent., while in most of the ore there is an appreciable quantity of silver, reaching, in some portions, as much as twenty-five to forty dollars per ton of ore, but yielding, on the average, from four to five dollars. A certain amount of gold is also present, but, as no attempts have yet been made to save this, the quantity is unknown. Silver and gold.

These mines are situated in what we now regard as the Sherbrooke and Stoke mountain anticlinal, and the rocks are chloritic, micaceous and talcose schists, with diorites. On this belt of rocks, southwest of Sherbrooke, and extending to the north line of Hatley, a large number of mines have been located, some of which have been worked for many years, while others, although containing valuable bodies of ore, have been idle for some time. In the township of Hatley the deposits appear to be much less numerous ; the belt of schists becomes narrower, probably in part owing to the overlap of the black slates of the Cambrian system. The most southerly deposit of copper ore in this direction is near the upper end of Massawippi lake, on the west side, on lot nine, range six. At this place there appear to be two kinds of rock, the soft blackish and bluish pyritous slates being in contact with the hard quartzo-felspathic rocks of the mountain series. The contact is probably along a line of fault, and the ore, which is scattered through a width of eight to ten feet, is in the form of the yellow sulphide, but the shaft being filled with water, the quantity could not be ascertained ; a large amount of iron pyrite appears to be mixed with the copper ore. This is the Parnell mine. The only other mine located in this township is that on lot twenty-eight, range one, known as the Reid Hill mine. It has an elevation of 500 to 600 feet above the Massawippi river, and presents the appearance of six beds of the yellow sulphide, with iron pyrite, in a space of a fourth of a mile in breadth. Similar ores appear on the lots to the west, on ranges two, three and four adjoining. Considerable exploratory work was done at this place, and a level was driven in about 200 feet below the outcrop of the bed, but no details of the workings or subsequent exploration are at hand. Mines south of Sherbrooke.

Beginning with this mine and passing into Ascot, there appears to have been an unusual development of this variety of ore, more particularly in that portion to the south-west of the St. Francis river, though large and very valuable deposits have also been discovered in the extension, to the north-east, of this anticlinal. The ores are

apparently all yellow sulphides, and no less than fifty-five localities were at one time reported as copper-producing or giving good indications of the ore. In all, up to 1865, thirteen mines were operated, of which the localities may, for the sake of reference, be briefly noted as follows, but since that date several others have been opened:—

The Clark mine—Lot eleven, range seven.

The Sherbrooke mine— Lot twelve, range seven.

The Albert mine—Lot three, range eight.

The Eldorado or Capel mine— S.E. ¼ lot four, range eight.

The Victoria mine—N.E. ¼ lot four, range eight.

The Ascot mine—W. ½ lot eight, range eight.

The Parks mine—W. ½ lot twelve range eight.

The Short mine—Lot fourteen, range eight.

The Lower Canada mine—Lot three range nine.

The Marrington mine—N.E. ¼ lot six, range nine.

The Hill mine—E. ½ lot eight, range nine.

The Belvidere mine—Lot ten, range nine.

The Magog mine—Lot eleven, range nine.

The Griffith mine—Lot three, range eleven.

These are the mines mentiond in the report for 1866, and in addition, several other areas, not distinguished by any particular names, occur, on which a greater or less amount of development work has taken place. Several mines have also since been opened, which promise well in view of the present large demand for sulphur ores. Among these may be mentioned the Suffield mine, on lot three, range eleven; the Cillis, now the 'Howard,' on lot five, range eleven; the Hepburn mine, on lot seven, range nine; and the Moulton Hill mine, north of the St. Francis river, on lots twenty-three and four, range three. The width of the ore-bodies, or lenses, in this section is very great, in places being considerably over fifty feet, and the breadth of the ore-bearing rocks, south of Sherbrooke, is about three miles, while from the Parnell mine, on the south, to the Moulton Hill mine, on the north, the distance is about twenty miles. Still further to the north, again, in Garthby, large deposits of similar ore have been reported.

Large ore bodies.

The first reference to the copper ores of this section is found in the report of the Geol. Survey for 1847, where an outcrop of a vein in the

fifteenth lot of the seventh range, is mentioned as worthy of trial, which was found to contain, in addition to copper, small quantities of silver and gold; the latter, however, not in quantity to be of economic importance, but of interest as showing the possible presence of the precious metal in greater quantity in other veins of the vicinity. On the thirteenth lot of the same range, the continuation of this deposit carried copper pyrites in veins, distributed throughout a belt of thirty feet of chloritic slates. This lode, on lot fifteen, was at the time traced for a distance of about fifty yards, but from half to one-third of a mile, further to the south, could not be found. When first opened, it had a breadth of from ten to twelve inches. Up to 1858 no further interest appears to have been taken in these deposits, only two places being referred to in the report for that year, viz., that just mentioned and lot nineteen, same range, where a small vein of copper pyrites was seen in a railway cutting near Sherbrooke station on the Grand Trunk railway. In 1859 the Ascot mine was discovered by Thos. McCaw, of Montreal, at Haskill hill, and found upon examination to consist of a bed of copper pyrites mixed with iron pyrites, having a thickness of five to six feet, in a matrix composed of impure limestone and chloritic schist. This mine was, in the fall of 1863, purchased by an American company, who erected furnaces for smelting the copper ore at Lennoxville. In the Geology of Canada, 1863, reference is made to but three mines in this vicinity, viz.: the Ascot, Haskell Hill, the Belvidere and that first discovered and already described. The ore was similar throughout, and the breadth in the Belvidere lode was estimated at six feet. What was afterwards the Marrington mine on lot six of the ninth range, showed a vein of from two to three feet at the surface, with a large proportion of iron pyrites. During the next two years a very extensive development in mining took place; a large number of mines were opened and a very considerable quantity of ore extrated.

Silver.

From notes kindly furnished me by Mr. T. Macfarlane and by J. S. Hunter, now of Belleville, I am able to give a few notes in regard to some of these, not already made public.

The Clark mine is situated one mile and a half from the Lennoxville station, G.T.R., on lot eleven, range seven, Ascot. This was first opened in 1863, by Mr. Wm. Clarke, and was worked with more or less vigour for several years, principally by an American company, who took out a large quantity of ore. The work was carried on for the most part by means of open cuttings upon a vein said to have a thickness of eighteen feet, (?) and containing three and a half per cent

The Clark mine.

of metallic copper. This estimated thickness of the ore bed is, however, doubtless exaggerated, since, on the most reliable authority, the thickness never exceeded seven to eight feet, and gradually decreased to eighteen inches. In addition to surface workings, a pit was sunk to a depth of forty feet and a shaft to seventy-three feet. Further explorations were carried on in 1866, but without success, and in that year the mine was sold at sheriff's sale. No returns as to quantity or quality of output are at hand, and the mine has apparently remained idle since the date mentioned.

The Sherbrooke mine.

The Sherbrooke mine immediately adjoins that just described, to the south, and is traversed by the same lodes as are found in the Clark mine. It has been quite extensively explored on the surface, though not yet opened up by underground exploration. Several valuable deposits of pyrites are reported on this property, one of which is said to have a thickness of eight feet, while another was stated to be no less than seventy feet in width. (?) Assays by several persons give from $4.00 to $5.00 of gold, $11.00 per ton of silver, and from 30 to 40 per cent of sulphur.

A group of three mines, situated on lots three and four, range eight, and lot three, range nine, are worthy of special notice, not only from their early history, but from their great and growing importance at the present time. These comprise what were formerly known as the Lower Canada, or Hartford, now the Eustis or Crown mine, the Capel or Eldorado, and the Albert; the last named being now owned by the firm of G. H. Nichols & Co.

The Capel mine.

The Capel mine was so called from the name of the original owner of the property, Mr. Geo. Capel, and in 1863, chiefly through the agency of Mr. W. S. Hunter, three men, Mr. Hunter, Mr. Carlos Pierce and Mr. Capel, formed a company to develop the property on lots three and four of range eight. These gentlemen spent from eight to ten thousand dollars in exploratory work, and, finding the results satisfactory, divided the property into two portions; the eastern area, on range nine, being styled the Prince Albert mine. The property was soon acquired by Montreal capitalists, by whom mining operations were commenced, and have been carried on to the present day, though under changed ownership and management.

From the Montreal firm the property passed into the hands of Taylor and Sons of London, who adopted the Henderson process for the extraction of the metallic copper. This, however, after a thorough trial, failed to give satisfaction, and the mine was closed. The property subsequently changed hands, and was finally purchased by

Messrs. G. H, Nichols & Co., an American firm of ability, by whom the ores have, for the most part, being shipped to the sulphur works at New York or vicinity, for the manufacture of acid. Within the last three years, however, a somewhat extensive plant has been erected at the mine for the manufacture of sulphuric acid on the spot, as well as for that of superphosphate. Smelting works have also been still more recently started for the production of matte. The success of the present company is no doubt largely due to the saving of the sulphur and other by-products of the ore, in which the profit consists. The depreciation of the copper market at the time of the former management, combined with the loss of the sulphur, was such, that expenses apparently could not be met. The deposits at the Albert and Capel mines are doubtless a continuation of that found to the south-west at the Crown mine, formerly the Lower Canada. There the ore bed is an immense, but somewhat irregular deposit of chalcopyrite, mingled with much iron pyrites, yielding an average of four to five per cent. of copper, some of the ore being very rich, and in addition containing an appreciable amount of silver. The lode varies in width from four to over fifty feet, and has been worked to a depth of over 1,600 feet. At the Eustis or Crown mine also, smelting works have been erected, in which a large amount of matte is made, the sulphur in this case being wasted, but a very large proportion of the ore still goes in the raw state to the sulphuric acid works in the vicinity of New York, while the residue is treated for copper at the smelting works at Bergenport, New Jersey. The owners of the latter are the Eustis Mining Co. The ore at this mine apparently occurs conformably with the bedding; the irregularities in size being due to local thickening of the ore mass. Dykes of diorite are met with in the different under-ground workings, and can also be seen at the surface in the immediate vicinity of the mines. The rocks containing the lode are schists, often highly micaceous and talcose, but generally chloritic, which are traversed by numerous quartz veins. The ore is delivered on the railway, about half a mile distant from the Albert mine, by an elevated cable tramway, carrying the ore buckets, and from the Eustis property by a gravity tramway to the track, where it is dumped directly into the cars. From several assays of this ore the quantity of sulphur is found to vary somewhat, but averages 38 to 40 per cent:—

The Eustis mine.

Silver.

| | |
|---|---|
| Iron | 35 |
| Copper | 4 to 5 |

Silver, about one ounce per unit of copper, say 4 ounces per ton.

The Lower Canada mine, or the Crown mine, now so called, was discovered in 1865. For two or three years thereafter it was worked for copper alone, but subsequently for copper and sulphur. This mine is well described in the Geological Survey Report for 1866, from which the following abbreviated extract may be made as illustrating the character of the workings and of the ore at that date.

Character of the ore bodies.

The strata for a distance of 1,600 feet dip S. 30°-40°E. $<$ 40°-60°, and in this distance five shafts have been sunk in micaceous schist, to the south-east of a dolomite band, and to all appearances in the same bed of ore. In shaft No. 1, the ore is ten feet thick, the lower four feet of which is apparently an almost compact mass of the yellow sulphide of iron and copper. Upon this are two feet of similar character, but yielding only about five per cent of copper, and the upper four feet contain iron pyrites alone. No. 2 shaft 125 feet south-west of this, is sixty feet deep, and the ore bed is four feet and a half thick; the lowest part is similar to that in the first shaft, but is said to yield fifteen per cent. copper, while the remainder yields only three per cent. The ore bed, as shown in shafts Nos. 3 and 4, sunk to a depth of 75 and 132 feet respectively, is similar to that in No. 2, but in No. 5, sunk 90 feet, the bed is six feet and a half thick and vertical for eighty feet from the surface, thence dipping S. 40°E. $<$ 40°-50°. In the vertical part it contains only iron pyrites but below this sufficient copper pyrites becomes mixed with it to cause the bed to yield between three and four per cent. of metallic copper. Other bands of copper ore occur in this lot, on both sides of shaft No. 1.

Subsequently to the date of the above report, mining operations were vigorously carried on, and in addition to the copper, which was originally the sole object of the enterprise, the large amount of sulphur contained in the ore was utilized for the manufacture of sulphuric acid, both in Canada and the United States. Up to June, 1869, about 20,000 tons were smelted to 40 per cent. regulus on the spot. A very large quantity was shipped to acid works, the amount of sulphuric acid obtained being stated at one ton of 66° acid to each ton of ore.

The yield of ore from these mines at present is very large and apparently annually increasing. The output for 1889, taken from the returns of the Mining Review, was, from the Eustis mine, 34,089 tons, including 1,773 tons matte, and from G. H. Nichols & Co. 36,000 tons.

As regards some of the mines alluded to in the list given in a preceding page, but little can here be said. A considerable amount of exploratory work was done on some of these and the promise of fair sized ore beds seemed good, but, in most cases, this work was not

pushed to a sufficient depth to decide as to the actual value of the property. That this appears to be true can be seen by reference to the great mines of Capelton and by a comparison of the enormous size of the lode in the lower levels, with its rather limited extent at the surface. Among others, not noticed in the list of 1866, may be mentioned the Suffield mine, on lot two, range eleven; the Hepburn mine, on lot seven range nine, where a large amount of exploratory work appears to have been done; and the Cillis mine, on lot five, range eleven, which has, within the last year, been reopened to a greater depth, and the ore has been found to increase in quantity and quality so greatly that it is now considered an exceedingly valuable property. It has been purchased by an American syndicate and will be worked.

Hepburn mine.

From notes obtained by Mr. Willimott in 1882* the Hepburn mine was then being worked quite extensively. Like the Ascot and Suffield mines, it was the property of the Sherbrooke Mining and Smelting Co. A shaft was sunk to a depth of 156 feet, and at sixty feet a level had been driven for thirty feet, from which a north and south cross cut was made. The latter was carried 110 feet, at which distance a bed of yellow sulphide twenty-four feet thick was cut, averaging about seven per cent. metallic copper. The north cross cut was carried ten feet, where another bed of yellow ore was cut, said to be twenty-seven feet thick. No ore has been raised, the object of the company being to develop a large reserve.

About twenty men were employed at the mine. Work at this property was shortly afterwards abandoned. The quality of the ore in the dump, seen in 1885, looked well. Of the Suffield mine, Mr. Willimott says: 'A shaft has been sunk 200 feet; at the depths of eighty-five feet, and two hundred feet, levels have been driven to the east, the former 300 feet and the latter 100 feet, connected by a ventilating winze.'

The amount of exposed ore is reported at about 40,000 tons, of which 3,500 to 4,000 tons have been taken out with the intention of concentrating and smelting at the mine.

At this mine the drilling was done by compressed air, driven by an engine of sixty horse power.

Silver.

The ore resembled that from the Capelton and Hartford mine, an assay of which was made by Dr. Harrington in 1877, yielding 75·03 ounces of silver to the ton. Assays of the Suffield ore, by John Massey & Co., London, England, gave percentages of silver, varying from eight ounces to 235 ounces per ton and from four to twenty-nine per cent of metallic copper.

* See Geol. Surv. Rep. 1882-3-4

Areas north of St. Francis river.

In the area north of the St. Francis, deposits of ore occur precisely similar to that of Capelton, and in similar rocks. What has proved to be a very valuable deposit was found about three years ago by Mr. Burke, the owner of the land, on lots twenty-three and twenty-four of the third range of Ascot, which has since been somewhat extensively developed, and purchased by the same syndicate which acquired the Cillis mine. The bed of ore which dips with the slate south-easterly at an angle of 45°-50° was found to rapidly increase from the surface showing of four to six feet to a reported thickness of not far from fifty feet, at a depth of seventy feet, revealing an enormous body of ore. This location was revealed by the uprooting of a tree, and is in the direct course of the Capelton deposit, which it so much resembles.

In view of the fact that these several ore beds, which are found over a breadth of some three to four miles, resemble each other very closely, and from the crumpled and overturned character of much of the strata in which they are contained, it seems most reasonable to suppose that the greater part of these mines were located upon different portions of the same lode, repeated by folding from place to place, and that as large and valuable deposits of the ore have been found at widely separated portions of the same vein, both in the southern and northern portions of the township, and almost equally valuable deposits are known in the more western portion of the belt, as at the Cillis mine, it may be very safely predicted that the real value of many of the mines which were opened twenty-five years ago and speedily closed, has never been ascertained, and that other masses of ore, of equal importance to those so long worked, will, by careful prospecting, be found at no distant date. Much of the failure of twenty-five years ago was, doubtless, due to the speculative character of the work done. Mines were bought and sold on the flimsiest sort of evidence as to their value or worthlessness; often on samples which were obtained from an entirely different location from that represented. The growing importance of these ores as a source of sulphur for sulphuric acid is being very fully realized by the men interested in this industry in the United States; their superiority over most of the United States ores, for this purpose, being acknowledged. There are yet, in this eastern belt, many places thickly covered by forest growth, the prospecting of which is a difficult matter, but of the many mines already opened and abandoned, it is highly probable, as in the case of those now worked, that deeper and more scientific testing would change the aspect of things greatly for the better.

Further to the north, in Garthby, a considerable deposit of pyrites is found on lot twenty-two of range one. This deposit is described in

the Geology of Can. 1863, p. 733, as 'a large mass of iron and copper pyrites, subordinate to the stratification of the enclosing rock which is a calcareous serpentine, dipping to the south-east at an angle of 50°. The extent of the deposit has not been determined, but there appears to be a breadth of about twenty feet, in which the two ores are more or less mingled with rock. Large masses of the mineral consist of a fine-grained iron pyrites, without any copper, while in other portions the ore is such an admixture of copper pyrites as to afford eight per cent. of the metal.' Garthby.

The ore at this place occurs in rocks differing in age from those of the area just described, being more closely allied to the deposits of Bolton and Potton. The first opening was made by Mr. J. B. Coulombe, in 1860, and was nine feet long, five feet wide, and said to be sixty feet deep. No work was done on the property after 1861. An analysis of the iron pyrites apparently free from copper gave iron 42, sulphur 48, copper 1·1, silica 8·9 per cent.

This property is about four miles from the Quebec Central railway, and recent explorations, during the past year, in the southern part of the area, are said to have developed a large body of ore, the associated rocks being traced into South Ham for a distance of three miles, but no definite information can be obtained on this point.

In the townships of Ham and South Ham, several mines were also at one time started, but these, apparently from an insufficiency of ore, have long since been closed. Among these may be mentioned the Nicolet Branch mines on lot twenty-eight, range four, where the variegated and vitreous ores were found scattered through a band of dolomite and chloritic schists, overlaid by glossy black slates. The ore is found in small veins only, disseminated through the rock, and by exploration over several hundred feet, several tons of rich ore were obtained. On range B, lots thirty-three to thirty-six, explorations were made on the right bank of the Nicolet river, on similar ores in green rocks, like the last, but without success, only small quantities apparently being found. In South Ham, in the serpentine and diorite rock of the south and east side of Nicolet lake, small deposits, mostly of the yellow sulphuret, occur on lot twenty-two, range one, old numbering, or lot forty-four, range one, new numbering. This was styled the Nicolet Copper mine. A small amount of exploratory work was also done on lot fifty-two, range two, new numbering, but no returns are at hand. Garthby. Ham and South Ham.

Further north, in the township of Thetford, copper ore has lately been reported by Dr. Jas. Reed, as occurring on lots three, four, five Thetford.

and six of the first range, and on lot fifteen of the second range of Leeds, as well as lot nineteen of the second range of Thetford, but the quantity and character of the ore are unknown, the locality not having yet been explored.

The more recent developments in connection with the copper ores of the province are taken from the reports of Mr. J. A. Dresser to this department, who devoted several season's work to their study over a large area; and from reports by Mr. J. Obalski, inspector of mines for the province.

Recent work by Prof. Dresser.

In his report for 1902, Mr. Dresser expresses the opinion that in the area of Cambrian rocks the copper occurs only in, or in close association with, igneous rocks of the district, all highly metamorphosed; that the ore does not occur as true veins, but in rudely lenticular masses, and that many of the rocks, formerly regarded as altered sediments in this association, are really altered volcanics.

In 1903, this view is somewhat elaborated and he says, 'the ore bodies have not been observed to form true veins in any case. In numerous cases they show in surface exposures, the elliptical outlines of much flattened lenses conforming to the foliation of the rock. The walls are not well defined and "horses" and lean ore masses are not infrequent within the larger ore bodies. The largest ore bodies were seen in the Eustis mine, where masses occur which are more than 100 feet in the least dimension, while they generally follow the dip and strike of the foliation which affords a useful means of tracing ore bodies; at times they also cross the plane of schistosity of the country rock at an oblique angle. Then they have more nearly the character of true veins. Such bodies appear to cut the dip more frequently than the strike of the enclosing rock The lenticular bodies also appear to be frequently arranged in echelon, since the lode, when lost, is most frequently recovered, not by following through the pinched out part along the strike, but by driving at right angles to it.'

Among new properties developed in recent years may be mentioned the following:

Melbourne.

Lot 7, range 1, Melbourne, by Mr. W. F. E. Bowes of Chicago, who opened up a deposit of copper pyrites and bornite in stringers in quartz, by a shaft seven feet and a half square, to a vertical depth of 50 feet, the copper-bearing portion being about a fourth of the width. The copper pyrites was said to yield 24 per cent. of copper and 32 per cent. of sulphur; the bornite 19 per cent, of copper and the same of sulphur with gold reported at $9 per ton.

Several of the old mines have been reopened to some extent, including the Ely, the Balrath of Melbourne, and certain areas in Leeds, Shipton, Brome and Chester.

On lots 17 and 18, range III, of Weedon, iron and copper pyrite is found in veins, masses and grains in the country rock but the property is not yet developed.

The new belt of copper-bearing rocks which has been indicated by Mr. Dresser as occurring adjacent to the Maine boundary in the Megantic district, shows the presence of large areas of volcanics. Copper and iron pyrites were found on the line of the Canadian Pacific railway at the 189th mile post from Montreal, exposed in a cutting through a belt of rusty rock of twenty rods in extent. The central part of the cutting shows the pyritous ores in a belt about ten yards in width, but as the cutting is oblique to this strike the actual width of this is somewhat less. The country in the direction is as yet largely wooded and unopened, but Mr. Dresser thinks from the nature of these rocks that other deposits of copper ores will be found. This belt is probably in the line of that opened up in the townships of Risborough and Marlow on lots 1, 2 3, ranges XIV, XV and XVI of the latter, and described in the Report by the writer for 1888-89, as carrying galena, pyrite and blende ores, with which also the somewhat rare mineral scheelite is found in considerable quantity, as ascertained by Mr. W. F. Ferrier, some years ago. At that time similar ores were reported as being found in the township of Spaulding and at several points in Ditton and Emberton, which are all within this fourth copper belt of the Eastern townships.

The Eastern belt or Megantic area.

Sheelite.

The Smith mine at Hogs Back mountain, near Knowlton landing, has, since the report for 1888-89, been further developed by sinking a shaft about 80 feet deep, and by a horizontal tunnel one hundred feet in length cross-cutting the ore body in the shaft at 50 feet from the surface. The ore carries from 1 to 7 per cent of copper with about 35 per cent of sulphur and a small percentage of nickel, and is a pyrrhotite. A considerable body of bog ore forms a capping over the main ore body and this has been shipped to the furnaces at Drummondville for the manufacture of iron. There appears to be a very large body of the pyrrhotite at this place, but beyond development work to a limited extent, but little mining has recently been done. It occurs along the contact of the diorites of the Hogs Back and Sugar Loaf mountains with the belt of black slates which traverses this district.

Smith mine lake Memphremagog.

Nickel.